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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

for

CHARACTERIZATION OF THE PHYSICO-CHEMICAL PROPERTIES OF POLYMERIC MATERIALS FOR AEROSPACE FLIGHT

NSG-5009

Bowie State College
Bowie, Maryland 20715

(NASA-CR-160070) CHARACTERIZATION OF THE PHYSICO-CHEMICAL PROPERTIES OF POLYMERIC MATERIALS FOR AEROSPACE FLIGHT Semiannual Report (Bowie State Coll., Md.) 68 p HC A04/MF A01 CSCL 11G G3/27

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ABSTRACT

The differential thermal analyzer is a very suitable instrument for the rapid analytical study of the thermal behavior of battery electrodes. Solid samples can be studied in the range of 0°C - 500°C using the standard cell assembly. Thermal behavior of battery electrodes is automatically recorded by the analyzer and it can be used for qualitative analysis. A study is also being made of the behavior of battery electrodes which have been charged at different levels.

INTRODUCTION

Differential thermal analyses are conducted with a DuPont Model 900 DTA unit. DTA is a technique for studying the thermal behavior of materials as they undergo physical and chemical changes during heating and cooling. Two 4mm-diameter tubes, one containing sample and the other containing a reference material, such as glass beads, are heated at a uniform rate in a heating block. The temperature differential between the two tubes will remain zero as they are heated unless the sample undergoes an endothermic or exothermic reaction. A thermocouple is inserted in the tube containing the sample and another thermocouple is inserted in the tube containing the glass beads. The glass beads do not undergo any chemical change in the temperature range under study. As long as the temperature of the sample equals the temperature of reference material, the two thermocouples produce identical voltage and the net voltage differential is zero. When an exothermic or an endothermic change takes place in the sample, the sample temperature no longer equals the reference temperature and the resultant voltage differential reflects the difference in temperature and either a positive or negative ΔT peak on the graph results. The DTA unit plots the temperature of the heating block on the X-axis; on the Y-axis it plots the difference in temperature between the sample and the reference, ΔT. An exotherm is plotted as a rise from the base line; an endotherm as a decrease from the base line.

DISCUSSION OF THE RESULTS

Several positive and negative battery electrodes were analyzed. The negative plates show a first endotherm between 245°C - 250°C. This is a very large peak. The second endotherm occurs at 300°C which is indicative of the decomposition of $Cd(OH)_2$ (see graphs 1 to 6). In the analysis of positive plates, a first weak endotherm occurs at 100°C, which indicates loss of H_2O from $Ni(OH)_2(H_2O)_n$ molecules. A second, large, endotherm occurs in the range of 290°C - 300°C, which is indicative of the decomposition of $Ni(OH_2)$ to NiO and H_2O (see graphs 7 to 17).

ABSTRACT

Atomic Absorption Spectroscopy is used to determine nickel, cobalt, cadmium, and potassium content in battery electrolytes and electrodes. We are also determining the interference effects of one element in the presence of others. Atomic Absorption is a quick and accurate method for the determination of traces of the above mentioned metals.

Introduction

Sealed Ni-Cd cells have proved to be a useful and reliable rechargable source of power for aerospace applications. However, it has been found that sometimes these cells have failed.

Although it is not completely known what leads to such failures, it has been found experimently that some of the factors which contribute to the final failure of the batteries are :

1. Extent and nature of cycle regime
2. Operating temperature
3. Carbonate contamination
4. Cd migration
5. Nature and condition of seperator

The analysis of negative electrodes, positive electrodes, and of the electrolyte is also important.

A.A spectroscopy is being used to analyze the elements of interest (Ni, Cd, Co, and K) in the electrodes and electrolytes of the Ni-Cd cells.

These results have been compared with those obtained by standard chemical analysis method and are in agreement. A.A spectroscopy is much quicker and embraces virtually all alloying components contained in Ni-Cd cells.

This method is being used to analyze for concentration of trace metals in negative and positive electrodes of batteries. This should prove useful in determining the amount and effects of these trace metals in functioning and durability of Ni - Cd cells.

Instrumentation

A Perkin-Elmer Model 403 Atomic Absorption Spectrophotometer was used. This unit has a digital read-out panel. High intensity cathode tubes for Ni, Cd, and Co were used depending on which element was being measured. Operating conditions were generally those recommended in the Analytical Methods Book.

The steps listed below were followed in adjusting the Model 403 Spectrophotometer in preparation for performing the analysis.

1. The instrument and exhaust hood are turned on and allowed warm-up at the specified current given in the Analytical Method Book for two hours or until stability is achieved. Stability is achieved when no zero shift is apparent over a five minute interval.

2. The air supply is turned on and the air pressure is set at 62 lbs/sq. in.

3. The acetylene supply is turned on and acetylene pressure is set at 27 lbs./sq. in.

4. The burner is ignited.

5. The flame should be blue and transparent with an oxidizing region about 4 mm.

6. The slit control is set at the value given in the Analytical Methods Book for the respective elements.

7. The adjustment of the atomizer is made by turning the capillary outward until "blow-back" occurs, then, turning inward until absorption is maximized. Standard solutions are aspirated through a tube into the flame for not less that 15 seconds.

Known Solutions Preparation

The solutions used were prepared from standard solutions of 1000 (Parts per Million (PPM). The dilutions were made as follows:

10 ml of 1000 PPM standard solutions were diluted to a final volume of 500 ml with deionized water to give a solution of 20 PPM concentration. This 20 PPM solution was used as a stock solution. Further dilutions were made as follows:

1. 5 ml of 20 PPM solution was diluted with deionized water to give a final volume of 100 ml and a solution of 1 PPM.

2. 10 ml of 20 PPM solution was diluted to a final volume of 100 ml and a solution of 2 PPM.

3. Repeat the above procedure with 15 ml of stock solution to get 3 PPM solution.

4. Repeat above procedure with 20 ml stock solution to yield a solution of 4 PPM.

5. Repeat above procedure with 25 ml of stock solution to get a solution of 5 PPM.

6. Repeat above procedure with 30 ml of stock solution to get a solution of 6 PPM.

7. Repeat above procedure with 35 ml of stock solution to get a solution of 7 PPM.

8. Repeat above procedure with 40 ml of stock solution to get a solution of 8 PPM.

9. Repeat above procedure with 45 ml of stock solution to get a solution of 9 PPM.

10. 50 ml of stock solution are diluted with 50 ml deionized water to get a final solution of 10 PPM.

Drawing of Caliberation Curve

The Atomic Absorption Spectrophotometer readings are displaye-d in absorption but they can be readily converted by means of a table to percent absorption which varies almost linearly with concentration. The conversion table is provided in the Analytical Methods Book for Perkins-Elmer Model 403 A.A. spectrophotometer.

The instrument parameters are recorded with each set of data so they can be duplicated when corresponding sample runs are made. Each curve standars is run in ascending order of element concentration. Curves can be conveniently plotted on expanded logrithmic paper

Analysis of Samples

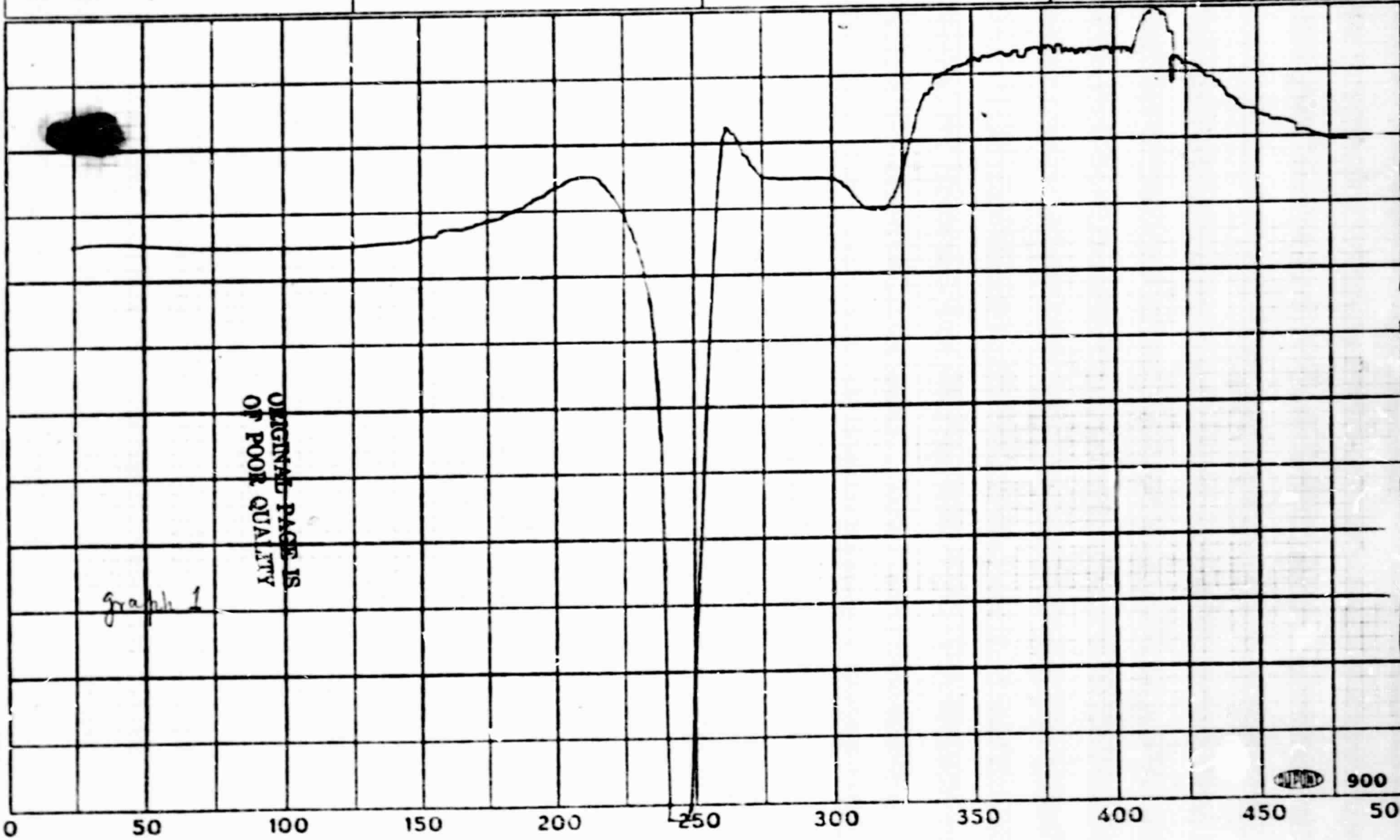
The agreement of the results obtained by A.A Spectroscopic analysis with those obtained by standard analysis have previously been confirmed (Please see annual report 1979).

For analysis of each sample a caliberation curve is derived from standard solutions. The given samples are diluted and the contration of the metal in the aliquot is calculated from the caliberation curve. This is multiplied by the dilution factor to give the concentration of the metal in the original sample.

The results obtained are given in table Ia through table XXb. Tables "a" contain the data for standard caliberation curve and tables "b" contain the data for analyzed samples.

The points corresponding to each analyzed sample have been marked on the caliberation curve.

SAMPLE: EP SN 202 Ncg 3	SIZE 3 mm in depth	ATM.	RUN NO. 11
	REF. glass beads	T: 50; ΔT: 1.0	DATE 6.27.70
	PROGRAM MODE heat	SCALE SETTING	OPERATOR C Khan
ORIGIN: Dr Vazant	RATE 6.0, START 25 °C		



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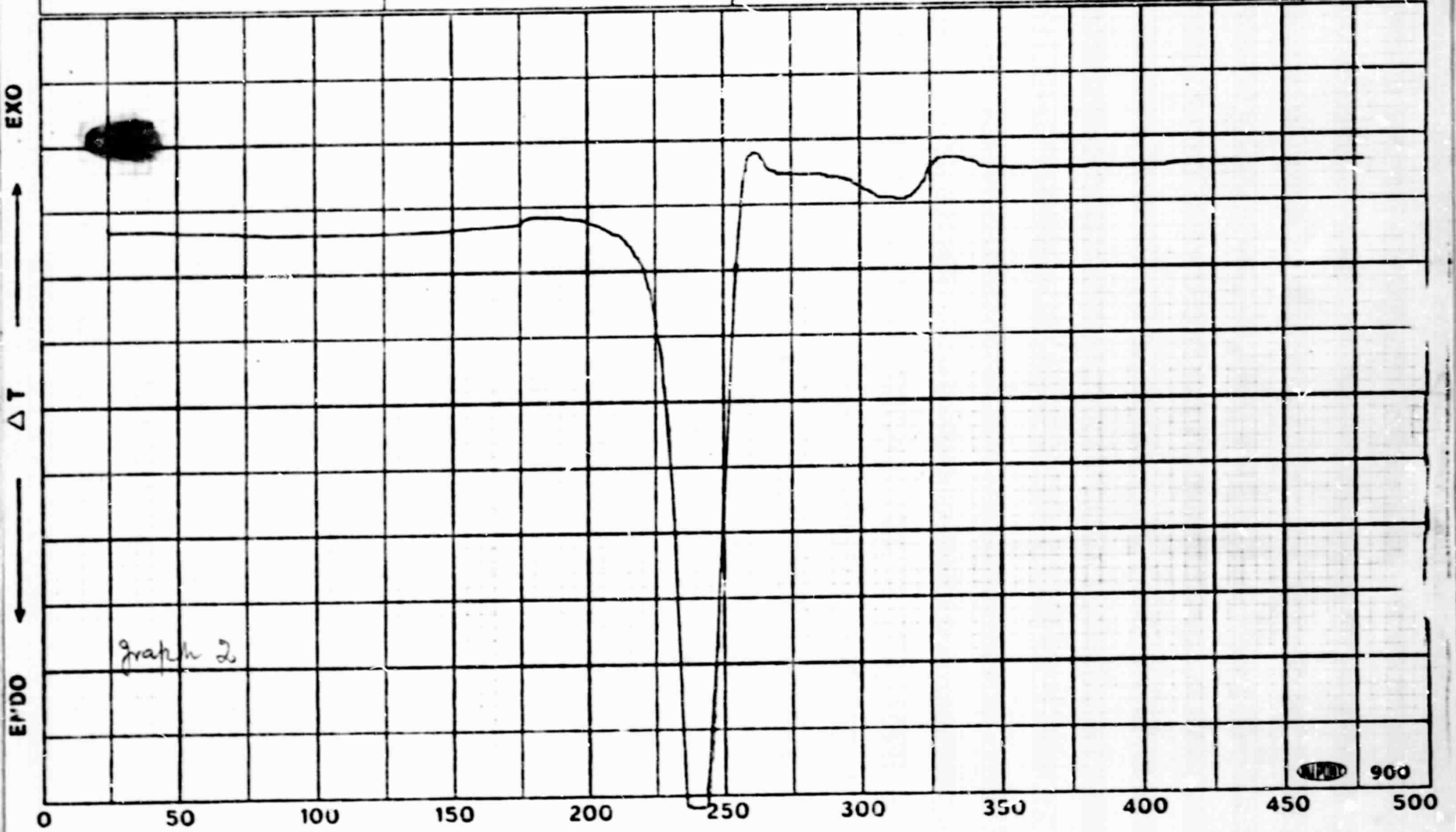
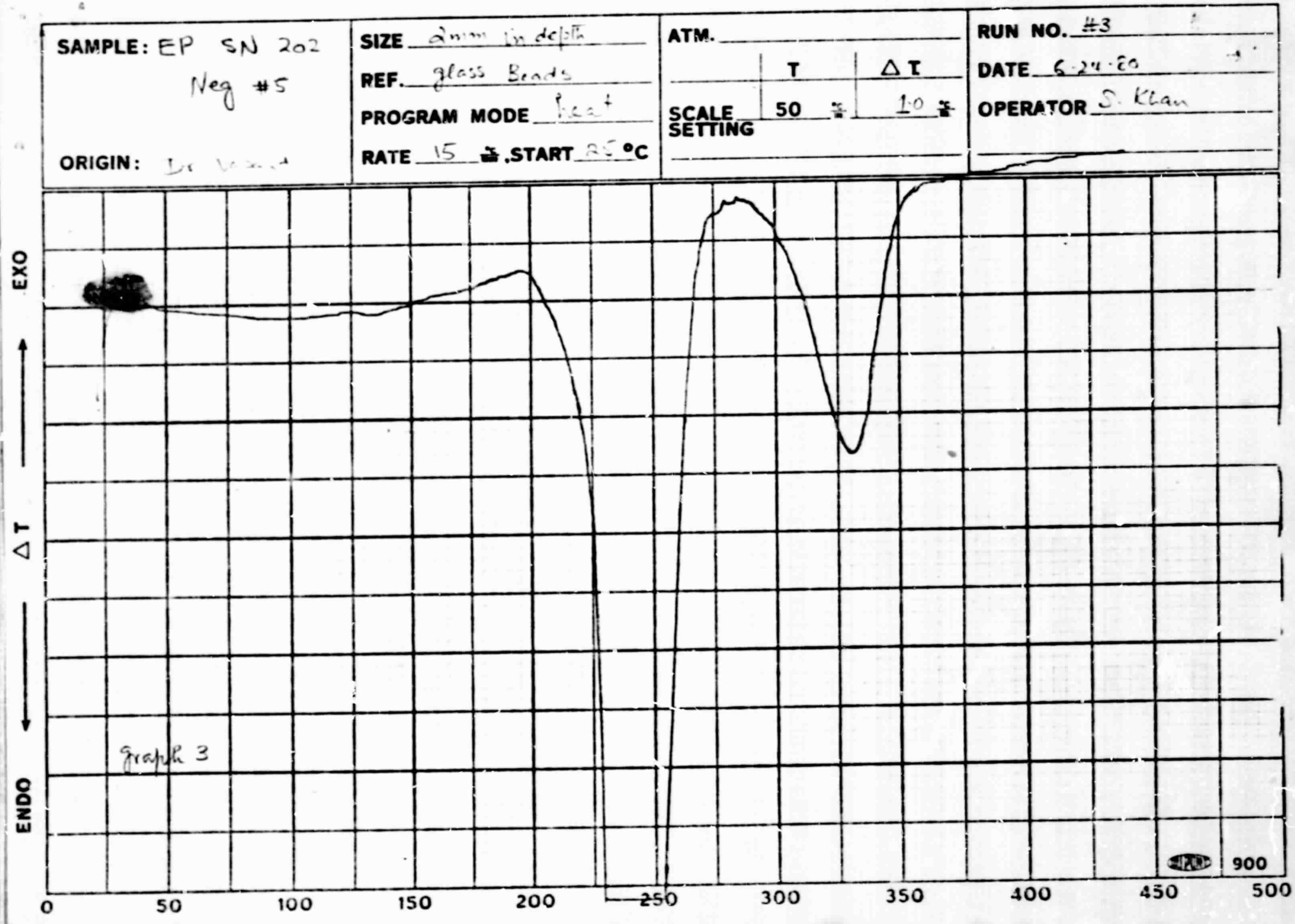
2

SAMPLE: Plate No 1	SIZE 2 mm deep	ATM.	RUN NO. 10
	REF. glass beads	T / ΔT	DATE 6-26-80
	PROGRAM MODE heat	SCALE SETTING 50 / 1	OPERATOR S. Khan
ORIGIN: Dr. Vasant	RATE 7.0 .START 25 °C		




SAMPLE: EP SN 202 Neg #5
ORIGIN: Dr Vasant
SIZE 2mm in depth
REF. glass Beads
PROGRAM MODE heat
RATE 15 °/min ,START 25 °C
ATM.
SCALE SETTING
T 50
ΔT 1.0
RUN NO. #3
DATE 6-24-80
OPERATOR S. Khan
EXO
ΔT
ENDO
Graph 3
900
0
50
100
150
200
250
300
350
400
450
500

SAMPLE: Neg Plate
Lot No- 555H
Part No- 805040

ORIGIN:

SIZE 3mm in depth

REF. 35437 beads

PROGRAM MODE heat

RATE 5 °C/min, START 25 °C

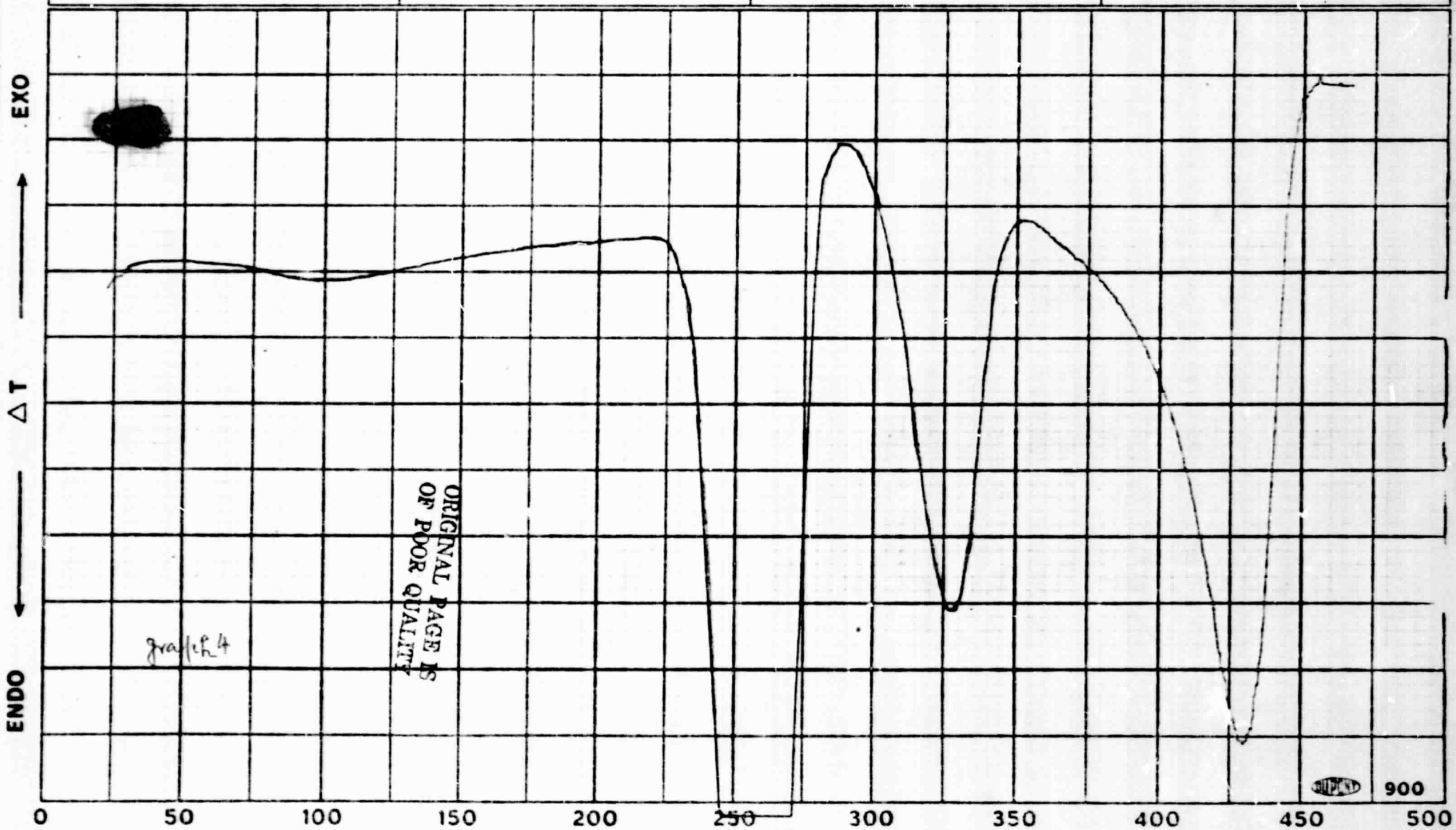
ATM.

SCALE SETTING	T	ΔT
	50 °C/in	1.0 °C/in

RUN NO. #4

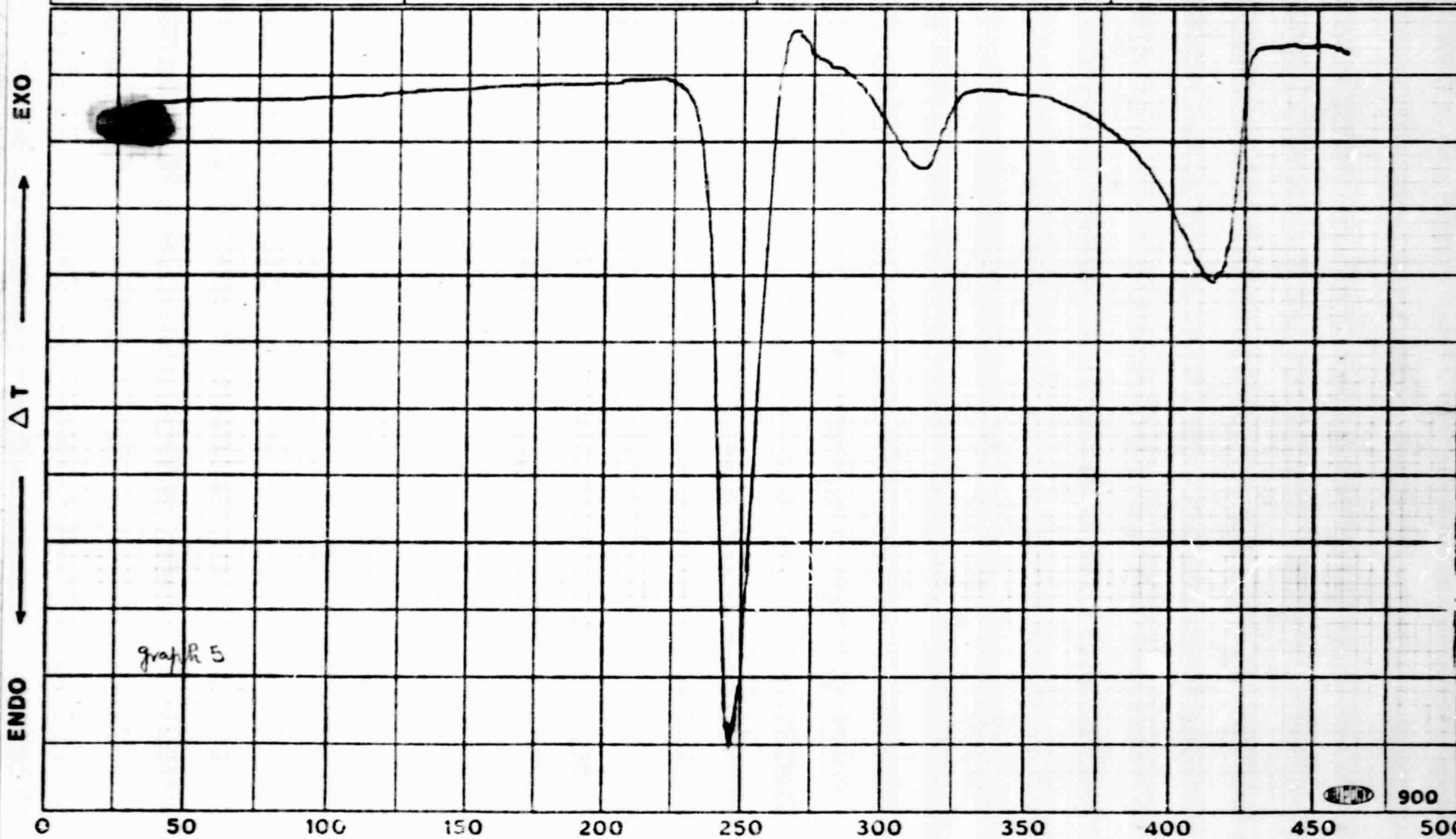
DATE 6·25·80

OPERATOR S·Khan

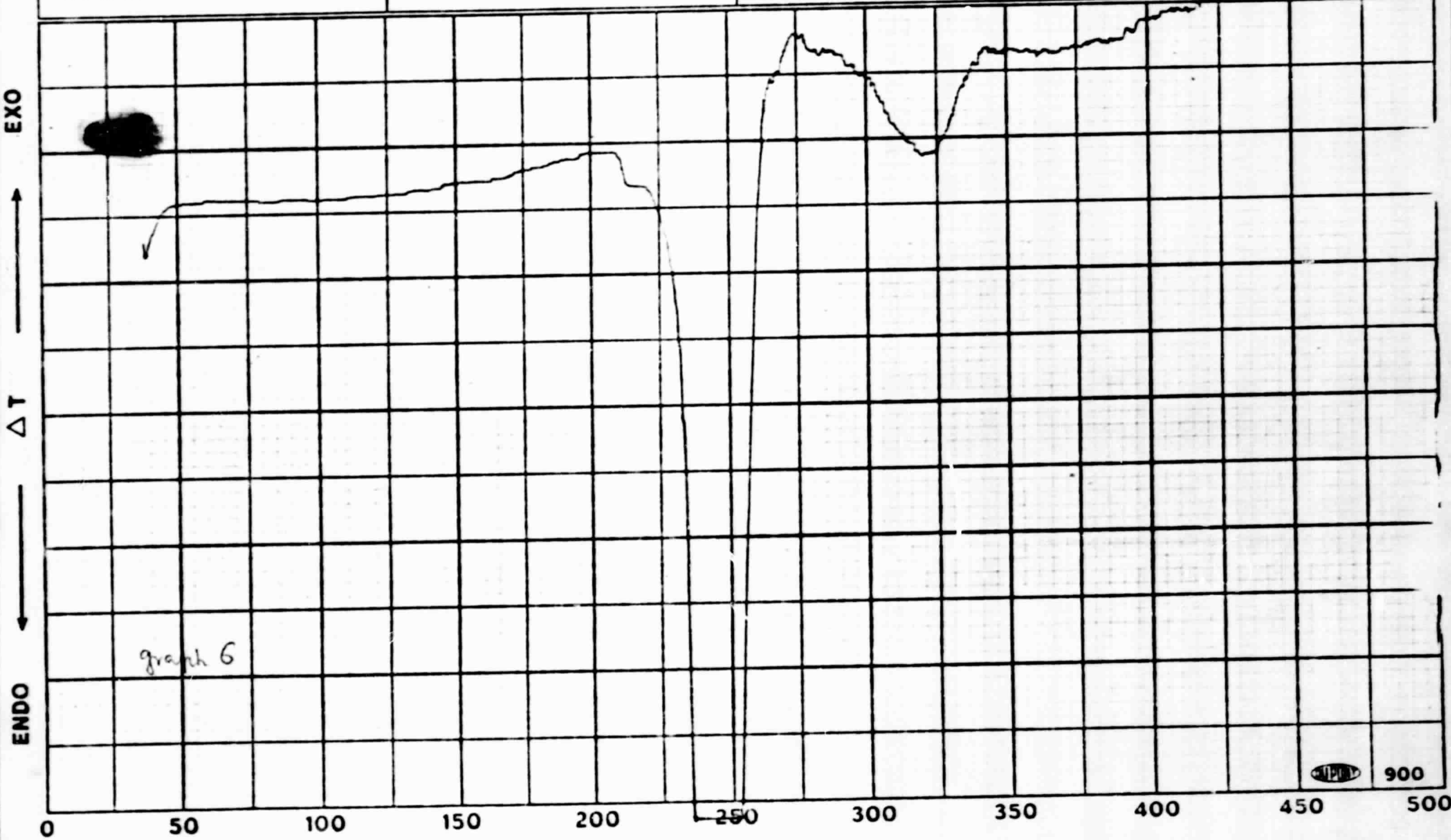


5

SAMPLE: Neg Plate	SIZE 5 mm in depth	ATM.	RUN NO. 14
Lot NO. 555 H	REF. glass beads	T / ΔT	DATE 6.30.80
Part No. 805040	PROGRAM MODE heat	SCALE SETTING 50 / 1.0	OPERATOR S. Khan
ORIGIN:	RATE 7.0, START Room °C 24		

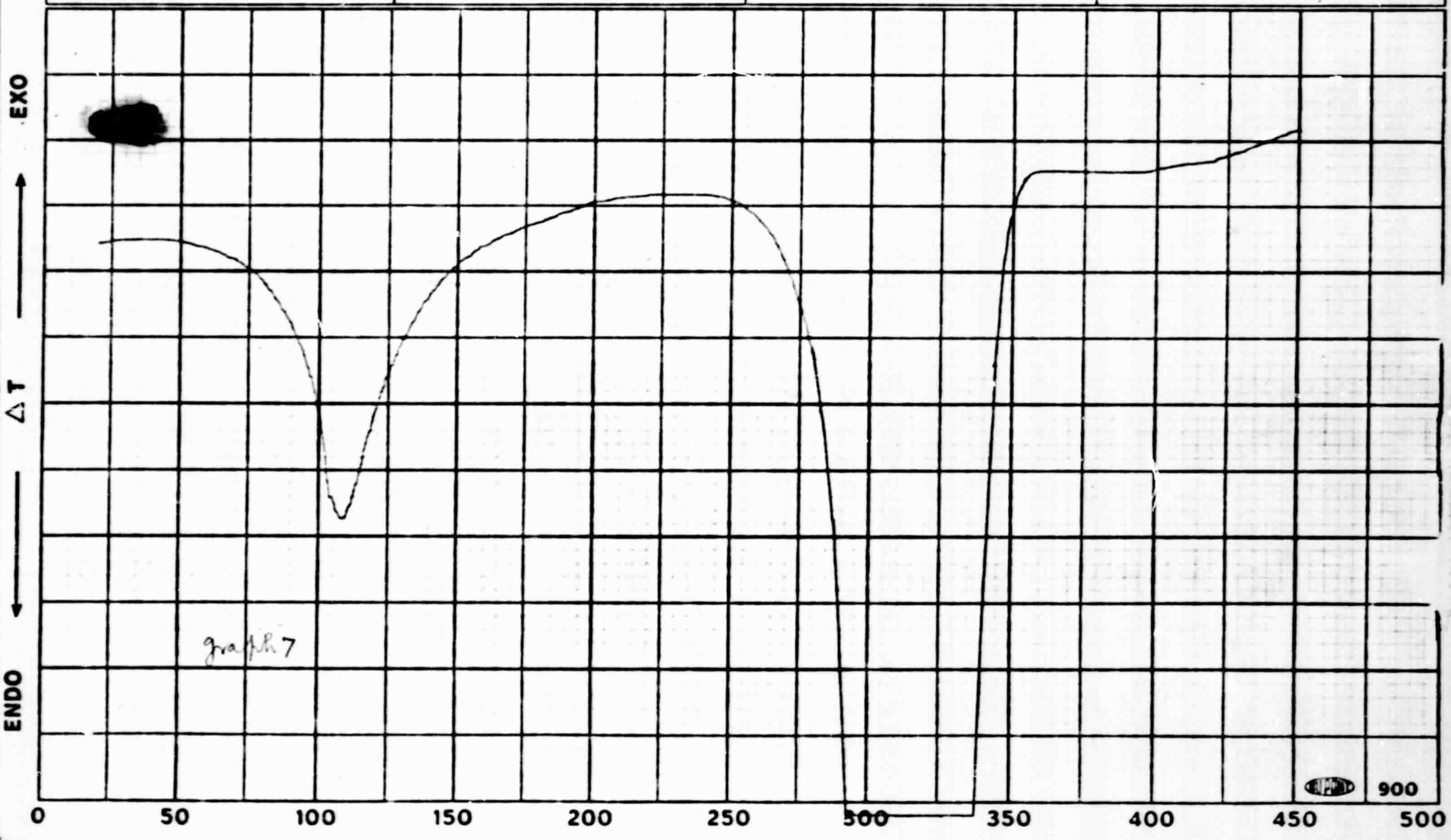


SAMPLE: GE 001 Neg Peak #17 Lot #2	**SIZE** [illegible]	**ATM.**	**RUN NO.** #6
	REF. glass beads	**SCALE SETTING** T: 50 °/in; ΔT: 1 °/in	**DATE** 6-25-80
ORIGIN:	**PROGRAM MODE** heat		**OPERATOR** C. Khan
	RATE 10 °/min, **START** 25°C		



7

SAMPLE: EP - SN 202 Pos # 2	SIZE 2mm deep REF. glass beads PROGRAM MODE heat	ATM.	RUN NO. 1
		SCALE SETTING: T 50 °C/in; ΔT 1 °C/in	DATE 6.24.80 OPERATOR S. Khan
ORIGIN: D. Vesant	RATE 15 °C/min, START 24 °C		



SAMPLE: EP-SN 2.02
Pos #12

ORIGIN: Dr. Vasant.

SIZE 2 mm in depth

REF.

PROGRAM MODE Prt

RATE 15 , START 24 °C

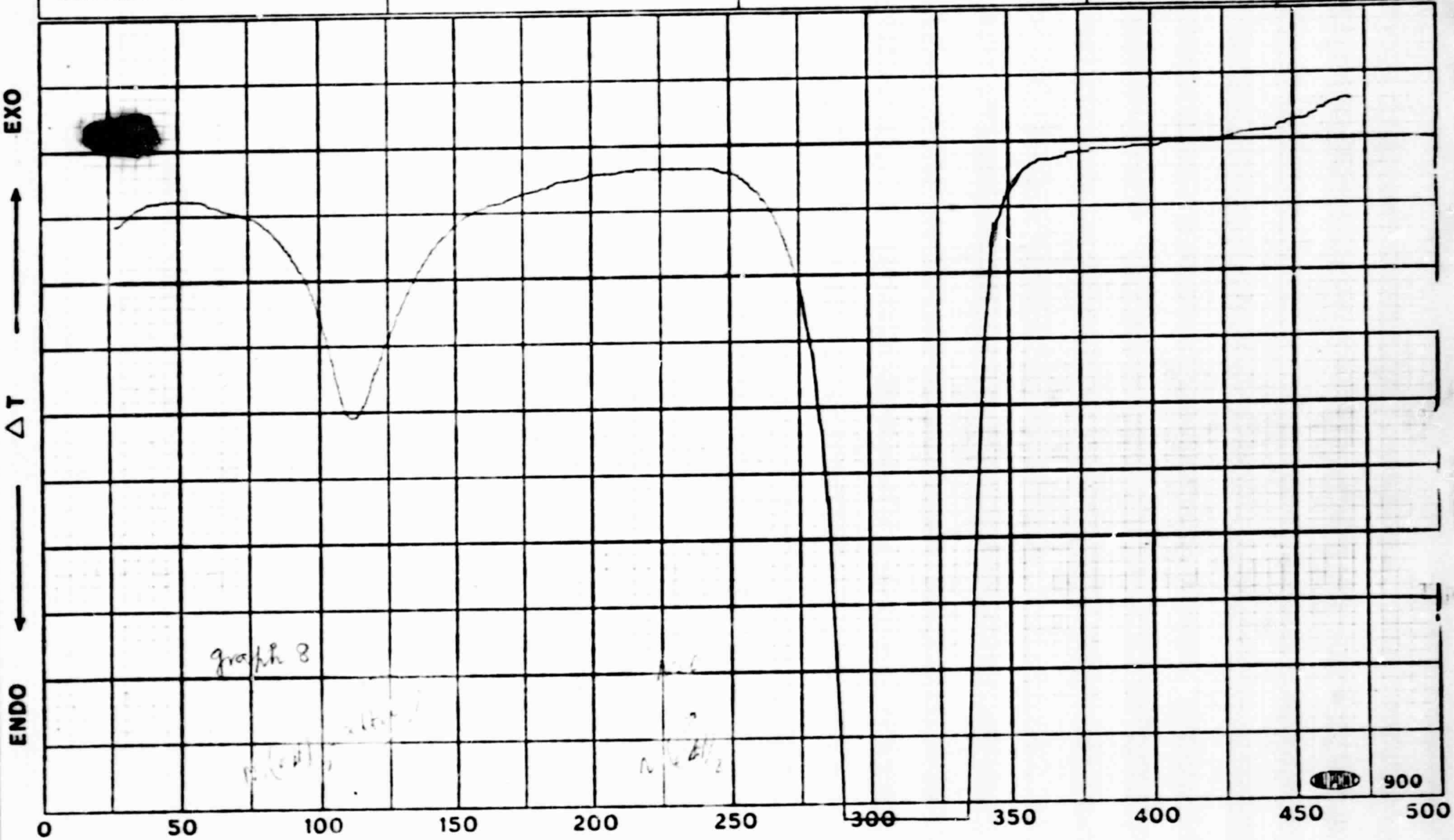
ATM.

	T	ΔT
SCALE SETTING	50	1

RUN NO. 2

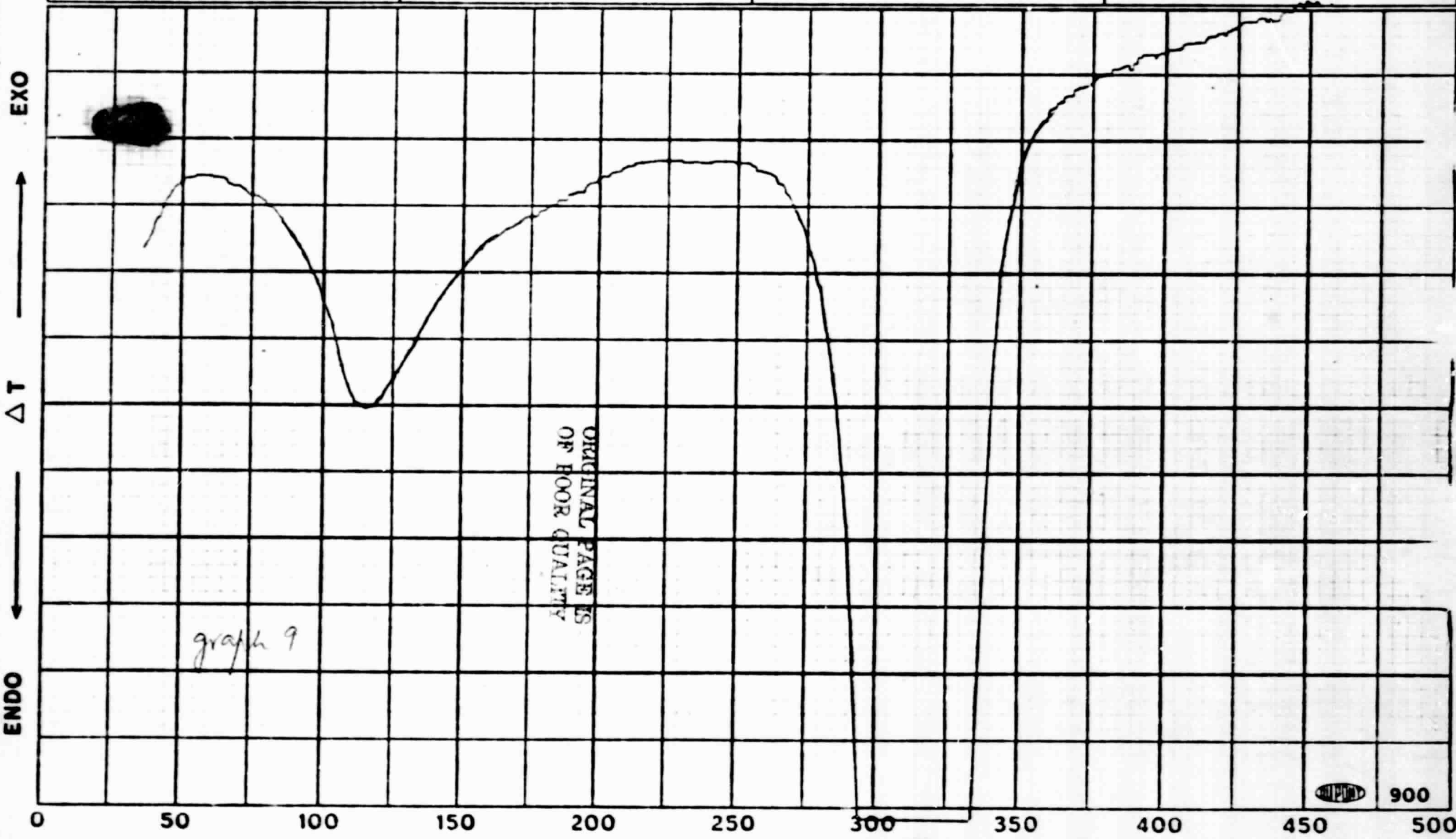
DATE 6·24·80

OPERATOR S. Kiran



9

SAMPLE: As Plates Lot NO. 553L Part No. 805039 ORIGIN: Dr. Vasant	SIZE [illegible] REF. glass Beads PROGRAM MODE Heat RATE 20 °C/min, START 25 °C	ATM. SCALE SETTING: T 50 °C/in; ΔT 1.0 °C/in	RUN NO. #5 DATE 6-25-80 OPERATOR Sher Khan



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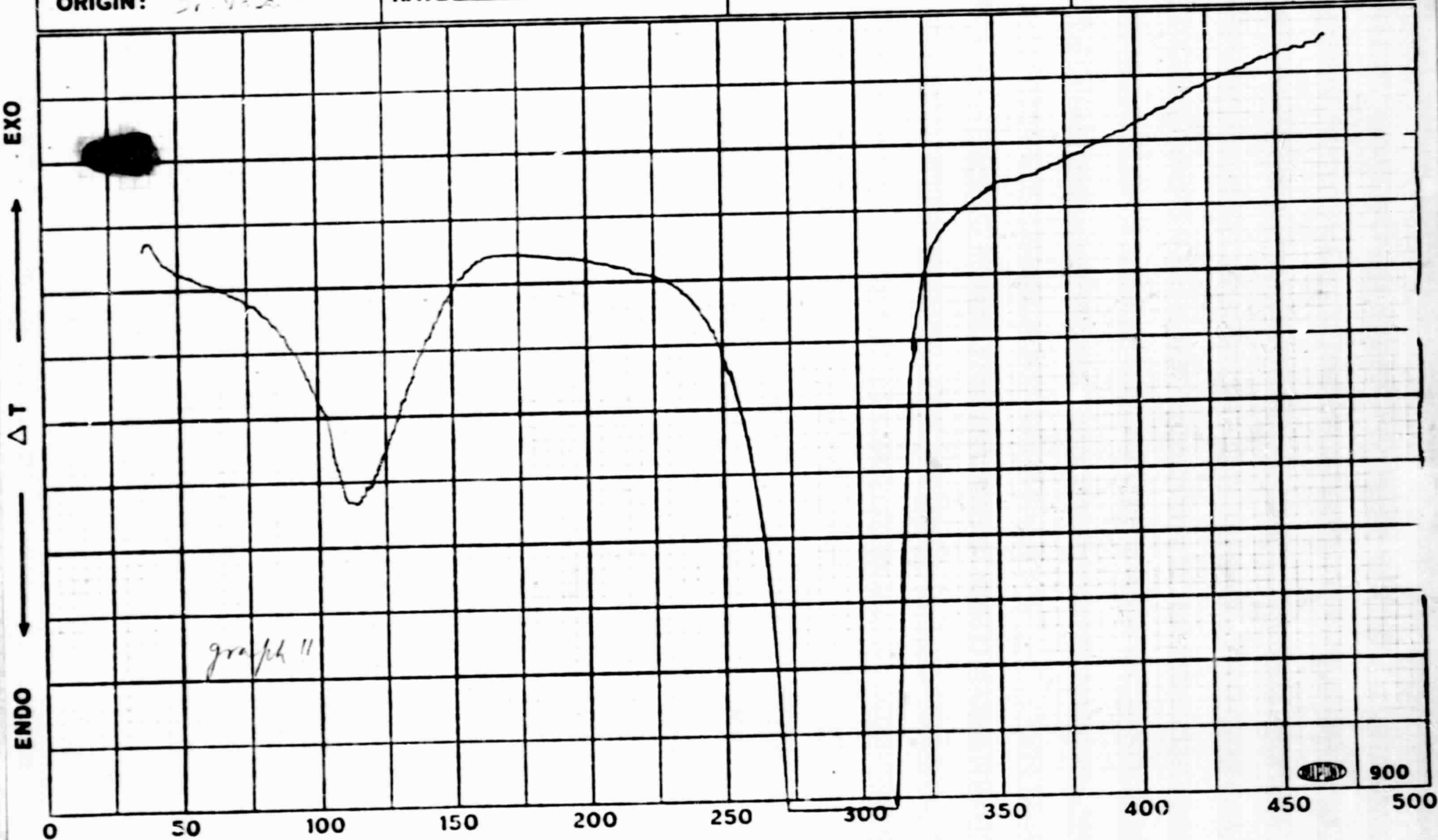
10

SAMPLE: PoC GE 001 Lot no. [illegible]	SIZE 2 mm in depth	ATM.	RUN NO. #7
	REF. glass beads	T: 50 ; ΔT: 1.0	DATE 6-26-80
	PROGRAM MODE heat	SCALE SETTING	OPERATOR [illegible]
ORIGIN:	RATE 15 , START 25 °C		

11

SAMPLE: TDRS 1	SIZE [illegible]	ATM.	RUN NO. 8
	REF. glass beads	SCALE SETTING: T 50 ; ΔT 1.0	DATE 6 25 80
	PROGRAM MODE heat		OPERATOR S. Khan
ORIGIN: [illegible]	RATE 15, START 24 °C		



12

SAMPLE: TDRS 2

ORIGIN: Dr. Vasant

SIZE 3mm in depth

REF. glass beads

PROGRAM MODE heat

RATE 15, START 25 °C

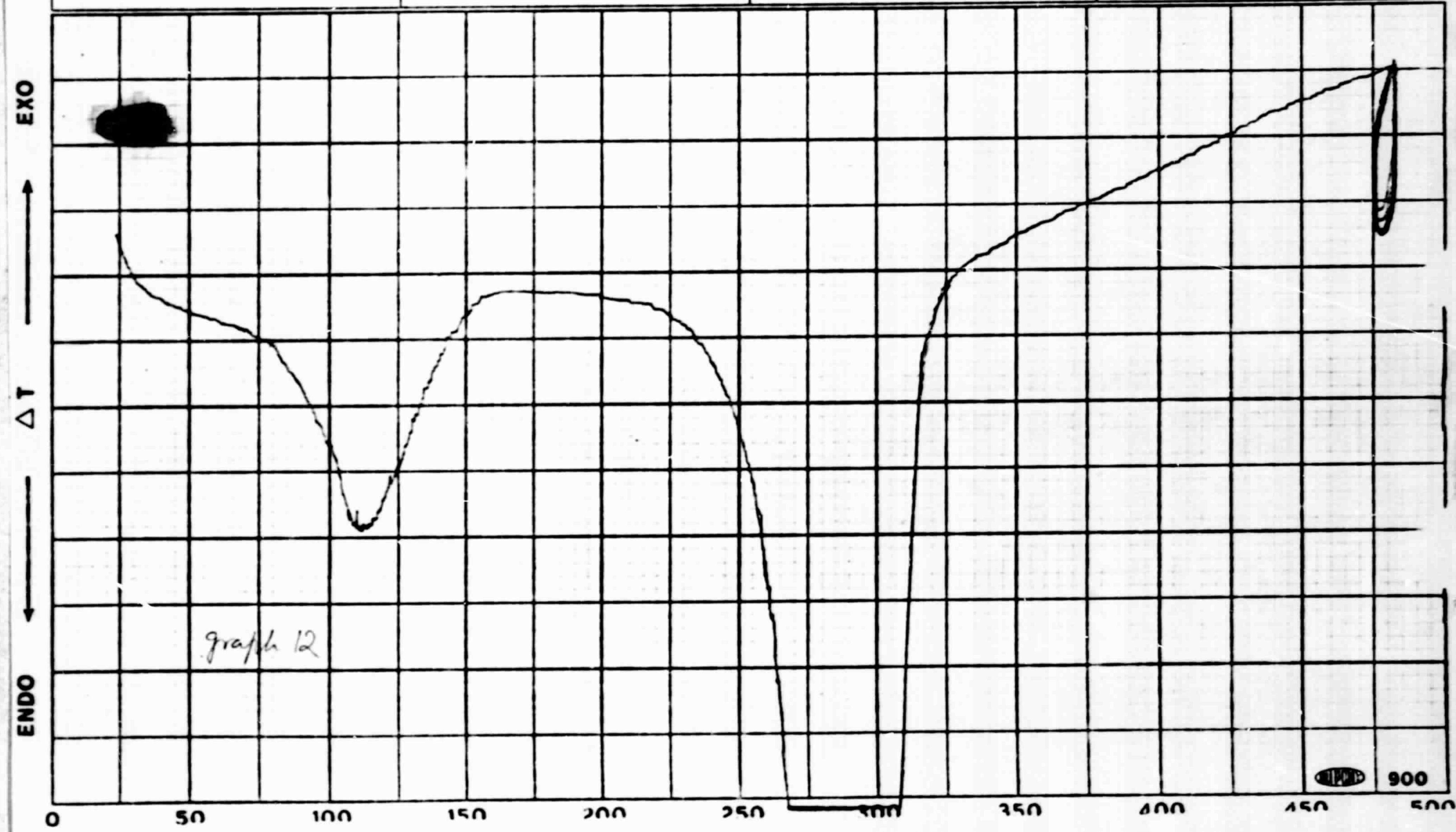
ATM.

	T	ΔT
SCALE SETTING	50	1.0

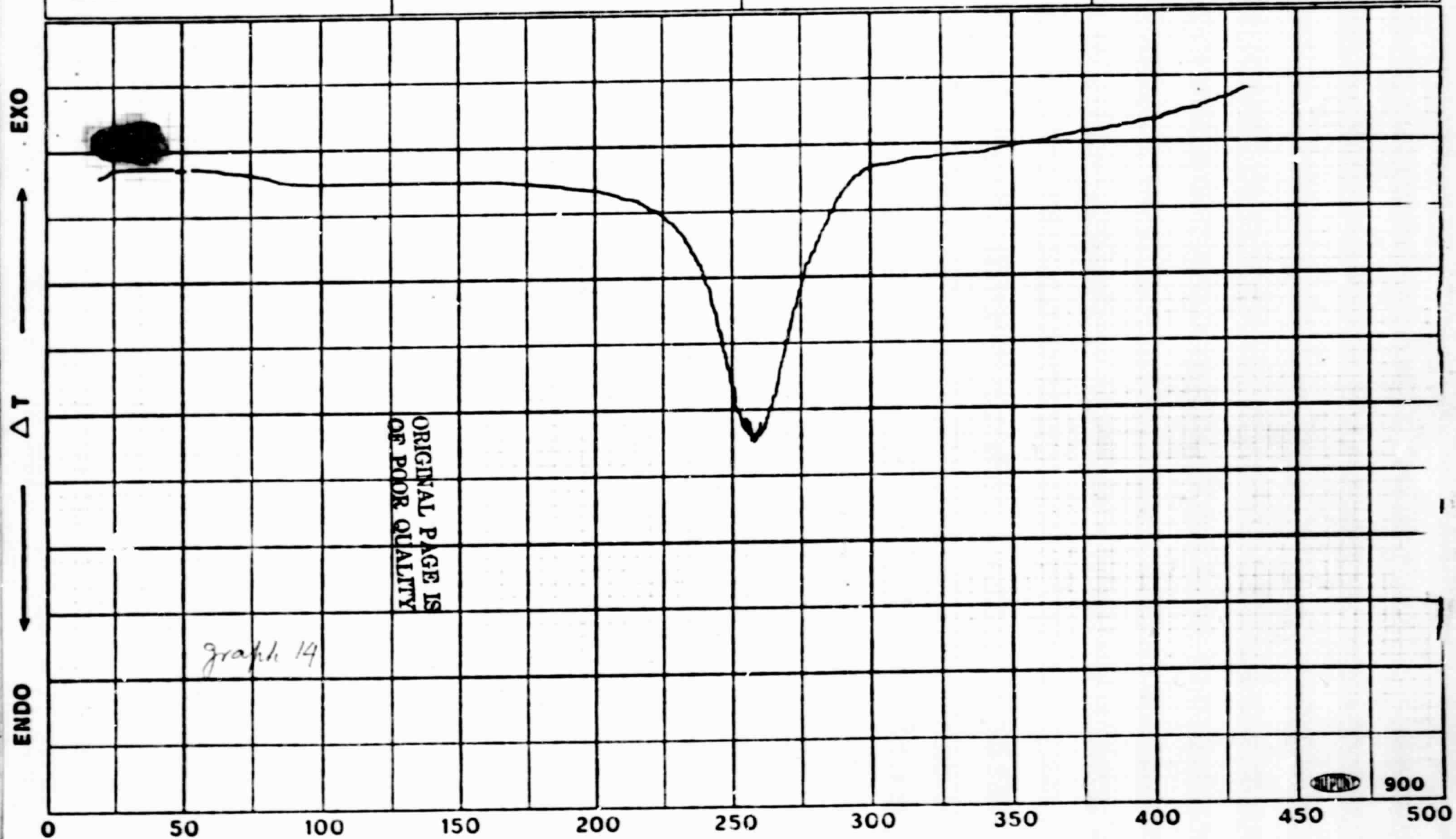
RUN NO. 9

DATE 6.26.80

OPERATOR S. Khan

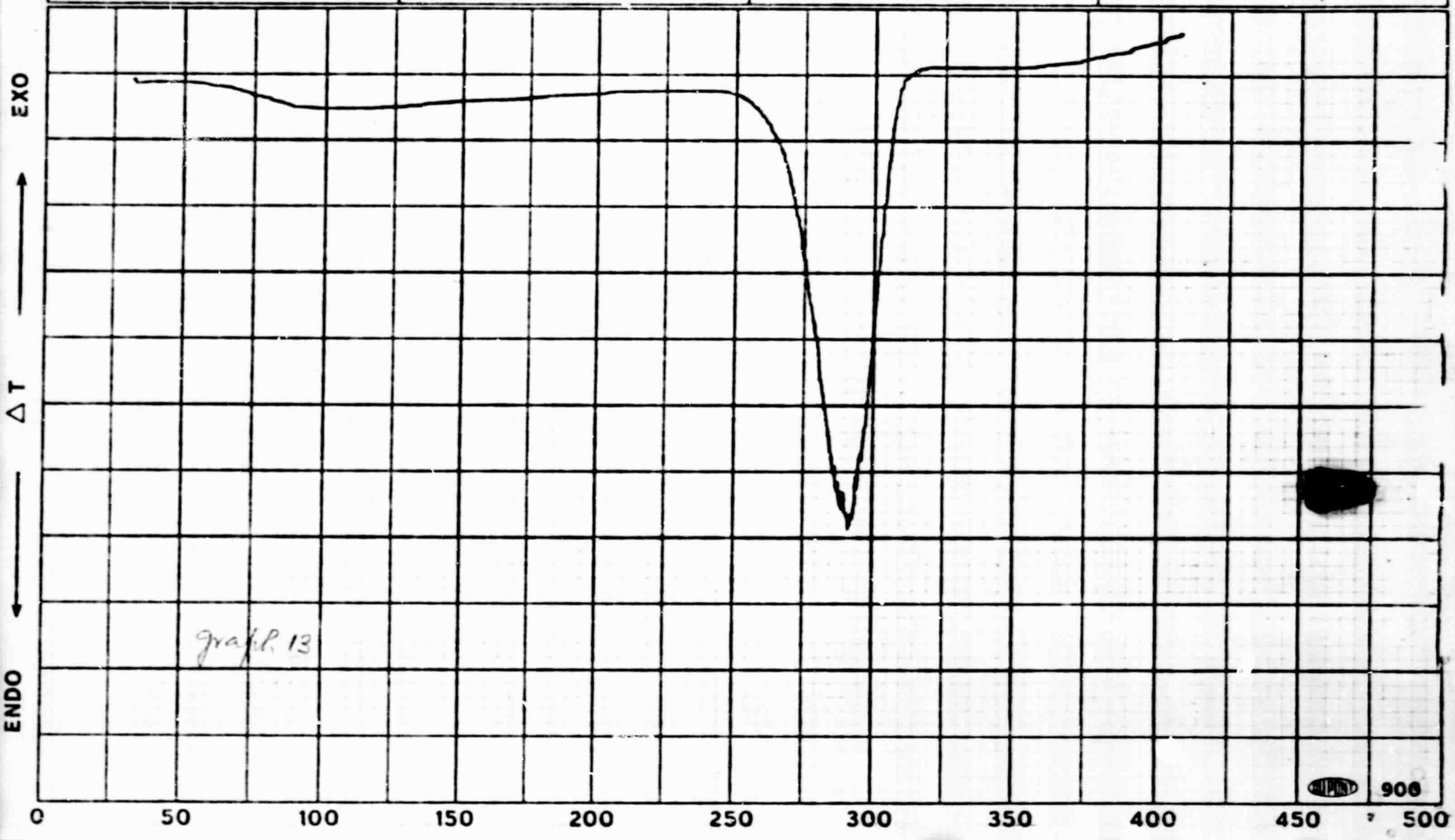


SAMPLE: Pos Plate Lot No 5572 Batch No 50583 Charged at 10ma/57ch	**SIZE** 2mm deep **REF.** glass beads **PROGRAM MODE** heat	**ATM.**	**RUN NO.** 17 **DATE** 7-3-22-8 **OPERATOR** Steiff
ORIGIN:	**RATE** ___ ,**START** 25°C	**SCALE SETTING** T: 50 ΔT:	

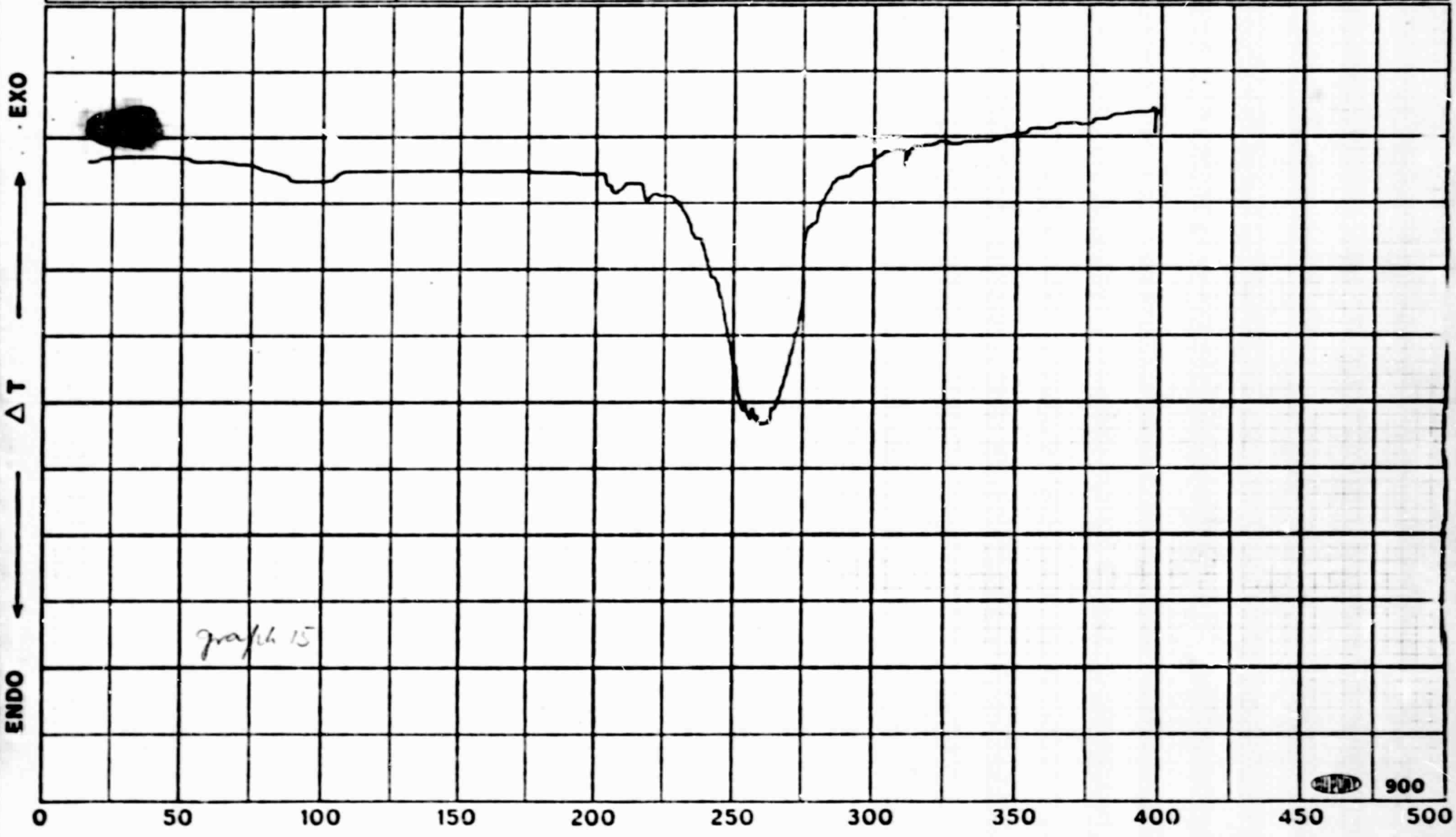


13

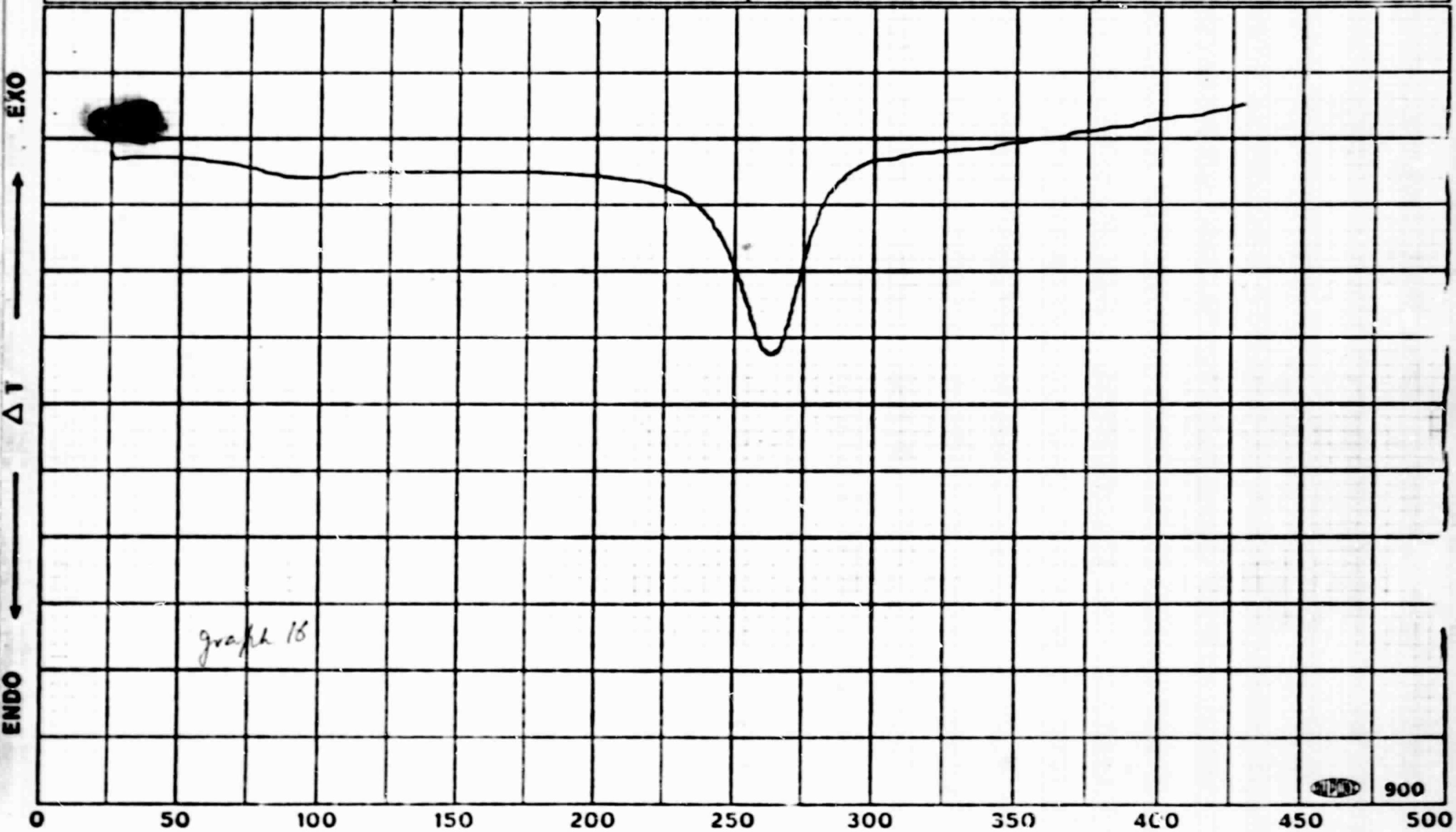
SAMPLE: Pos Plate Lot No 5572 Pc24 No 805039	SIZE 2mm in depth REF. glass beads PROGRAM MODE heat RATE -- °/min START 25 °C	ATM. SCALE SETTING: T 50 °/in; ΔT 1.0 °/in	RUN NO. #16 DATE 7-21-80 OPERATOR Staff
ORIGIN:			



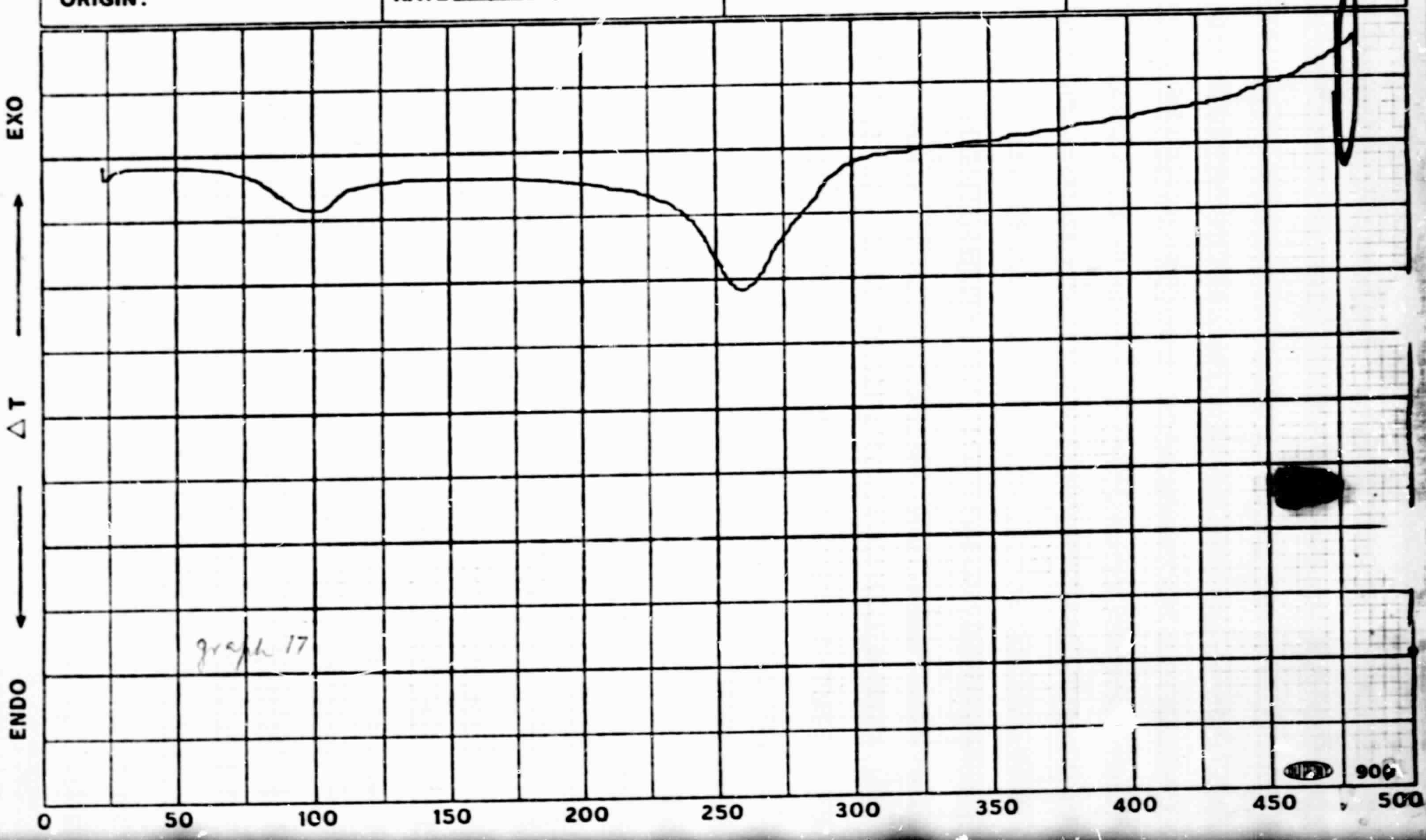
SAMPLE: Pos Plate Lot No 5332 Part No 865659 Charged at 30 ma/sq in ORIGIN:	SIZE 2mm deep REF. glass beads PROGRAM MODE heat RATE ___ ,START 25 °C	ATM. ___ SCALE SETTING T 50 ; ΔT 1.0	RUN NO. 18 DATE 7-24-80 OPERATOR Staff



SAMPLE: Pos Plate Lot NO 553L Part NO 805057 charged at 30 mf/sq in ORIGIN:	SIZE 2 mm deep REF. glass beads PROGRAM MODE heat RATE 7.0 °/min. START 25 °C	ATM. T | ΔT SCALE SETTING 50 °/in. | 1.0 °/in.	RUN NO. 19 DATE 7-28-80 OPERATOR Staff

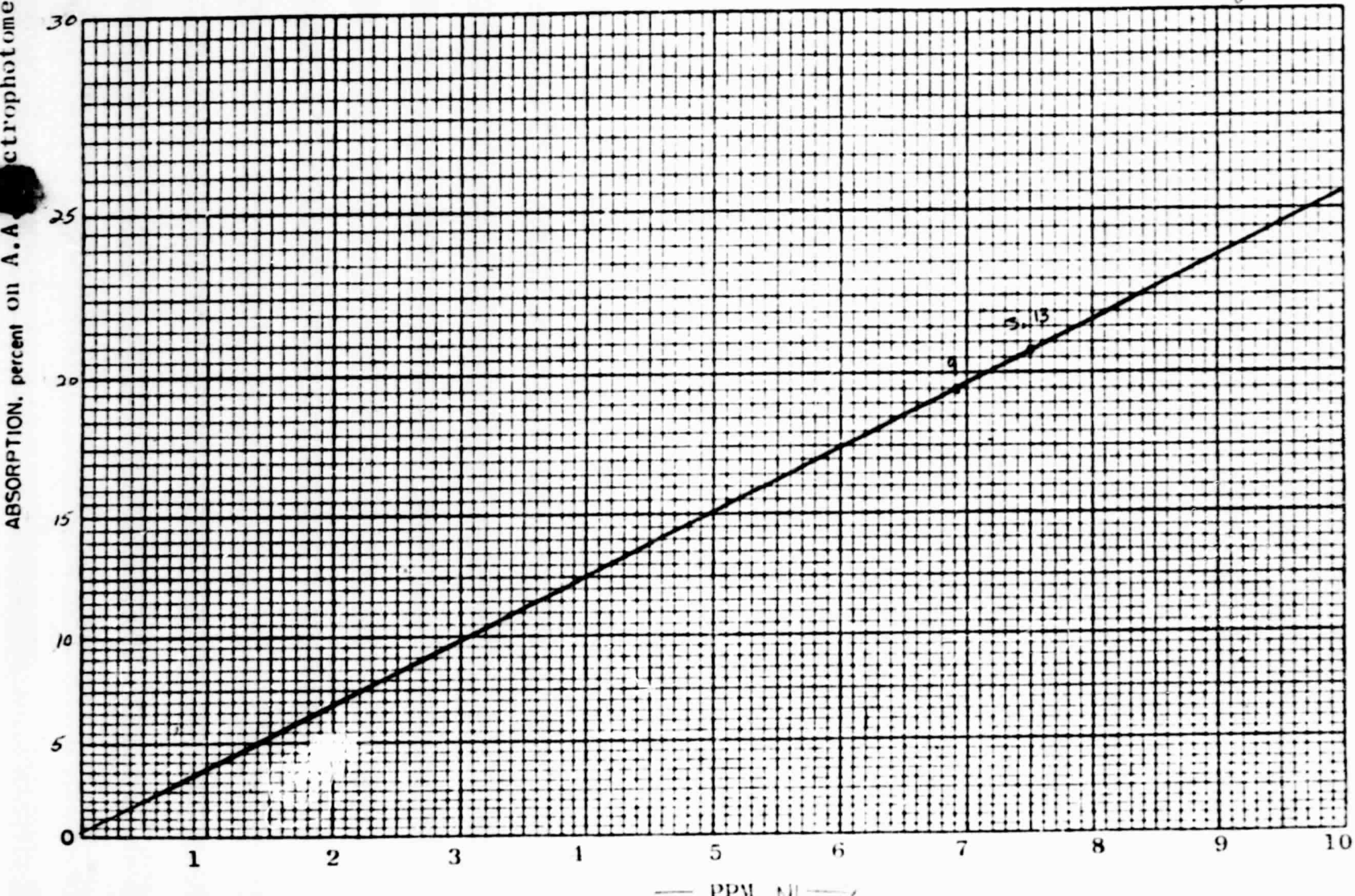


SAMPLE: Pos Plate Lot No 553L Part No- 805039 Charged at 40ma/sq in ORIGIN:	SIZE REF. PROGRAM MODE RATE 7.0 .START 25 °C	ATM. T / ΔT SCALE SETTING 50 / 1.0	RUN NO. DATE OPERATOR Stoll



Analysis of samples GE 12 AM SN 01 #3, #9, and #13.

Graph I



#3 = 7.5 PPM
#9 = 6.9 " "
#13 = 7.5 PPM

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Data for Graph I

Analysis of cell GE 12AM S/NO1 plates #3, #9, #13

Caliberation curve for **Ni**

Table Ia

PPM	A.A. Reading	%Abs
2	.0234	5.3
4	.044	9.7
6	.0644	13.8
8	.0842	17.6
10	.1011	22.4

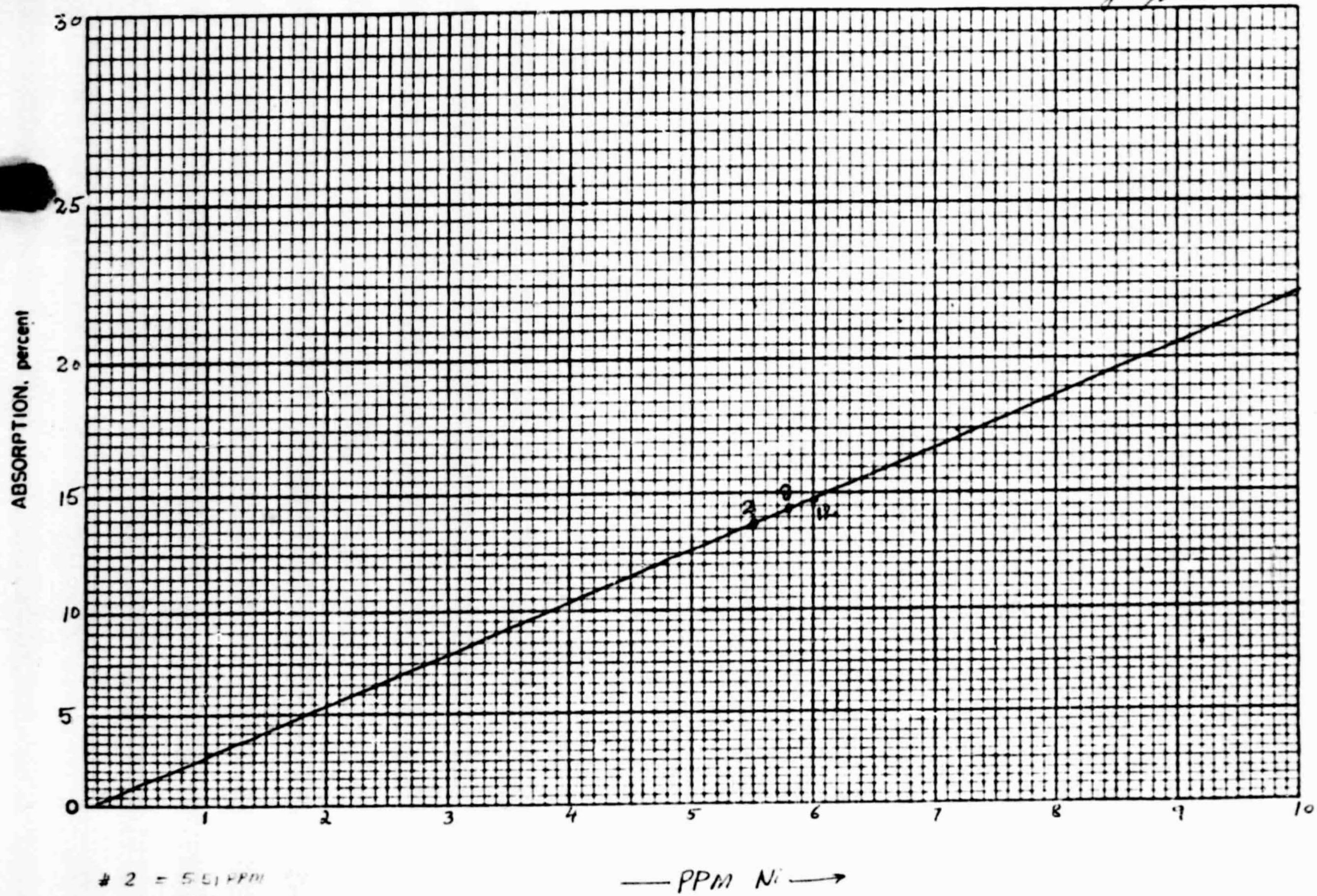
Unknown sample analysis

Table Ib

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 12AM S/NO1 #3	X 10	.079	16.7	7.5	75.0
GE 12AM S/NO1 #9	X 10	.0734	15.6	6.9	69.0
GE 12AM S/NO1#13	X 10	.0802	16.9	7.5	70.0

Analysis of samples GE 02 Positive #2, #8, and #12.

Graph 2



2 = 5.51 PPM
8 = 5.80 "
12 = 6.00 PPM

Data for Graph II

Ni analysis of cell GE 02 plates #2, #8, #12

Caliberation curve for Ni

Table IIa

PPM	A.A. Reading	%Abs
2	.030	8.0
4	.056	12.2
6	.082	17.3
8	.109	22.2
10	.128	25.5

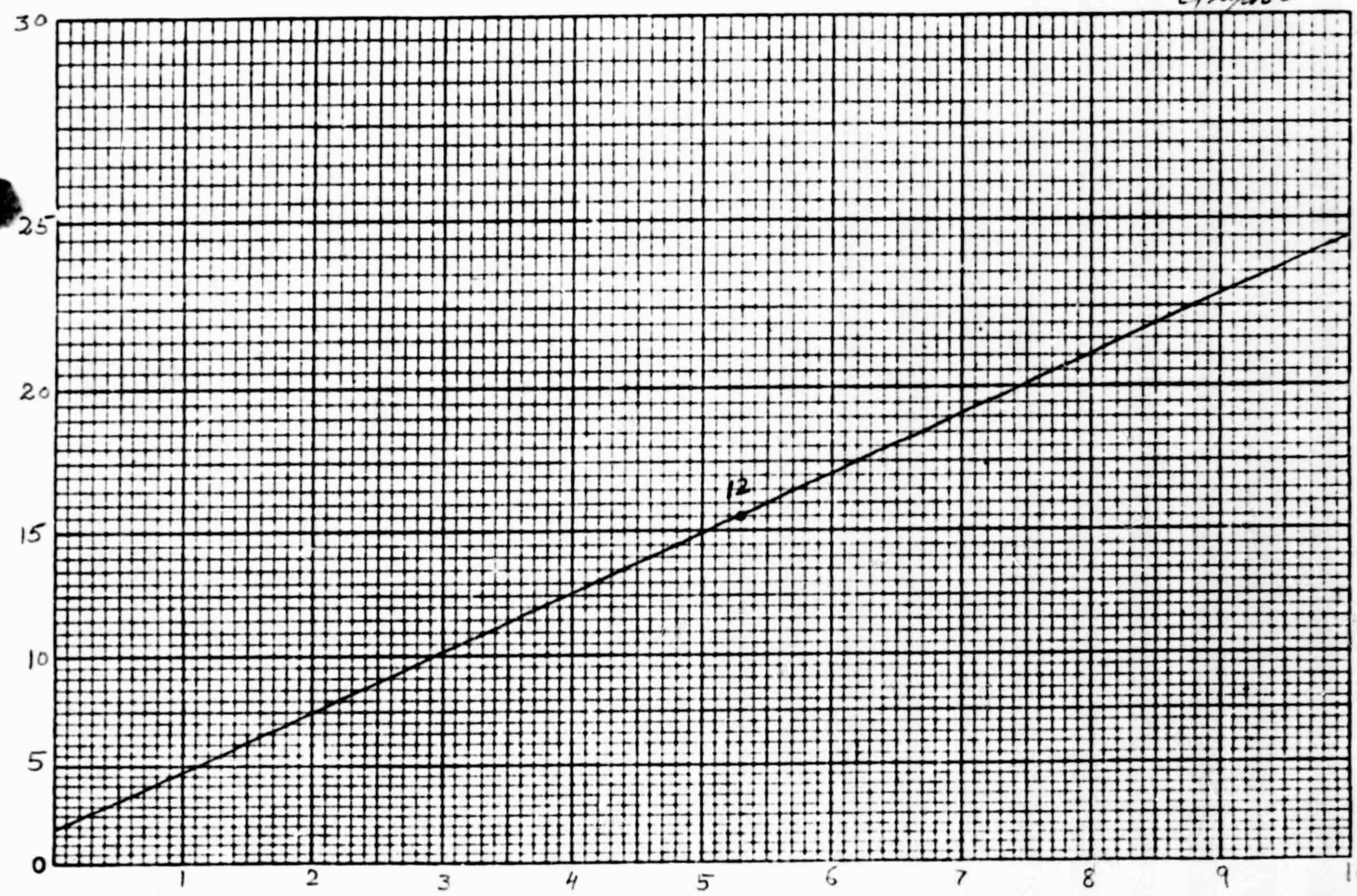
Unknown sample analysis

Table IIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 02 #2	250	.076	16.1	5.51	1380
" #8	"	.081	17.0	5.80	1480
" #12	"	.084	17.6	6.00	1500

Analysis of Sample GE 02 Positive #12

Graph 3



ABSORPTION, percent

— PPM Ni →

12 = 5.3 PPM

Data for Graph III

Ni analysis of cell GE 02 Positive plate #12

Caliberation curve for Ni

Table IIIa

PPM	A.A. Reading	%Abs
2	.0326	7.2
4	.576	12.4
6	.0834	17.5
8	.1088	22.3
10	.130	25.9

Unknown sample analysis

Table IIIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 02 Pos. #12	.250	.0745	15.8	5.30	1320.

Data for Graph IV

Ni analysis of cell GE 02 plates #3, #9, #13

Caliberation curve for Ni

Table IVa

PPM	A.A. Reading	%Abs
2	.021	4.7
4	.0398	7.8
6	.0622	13.3
8	.0802	15.9
10	.0920	19.2

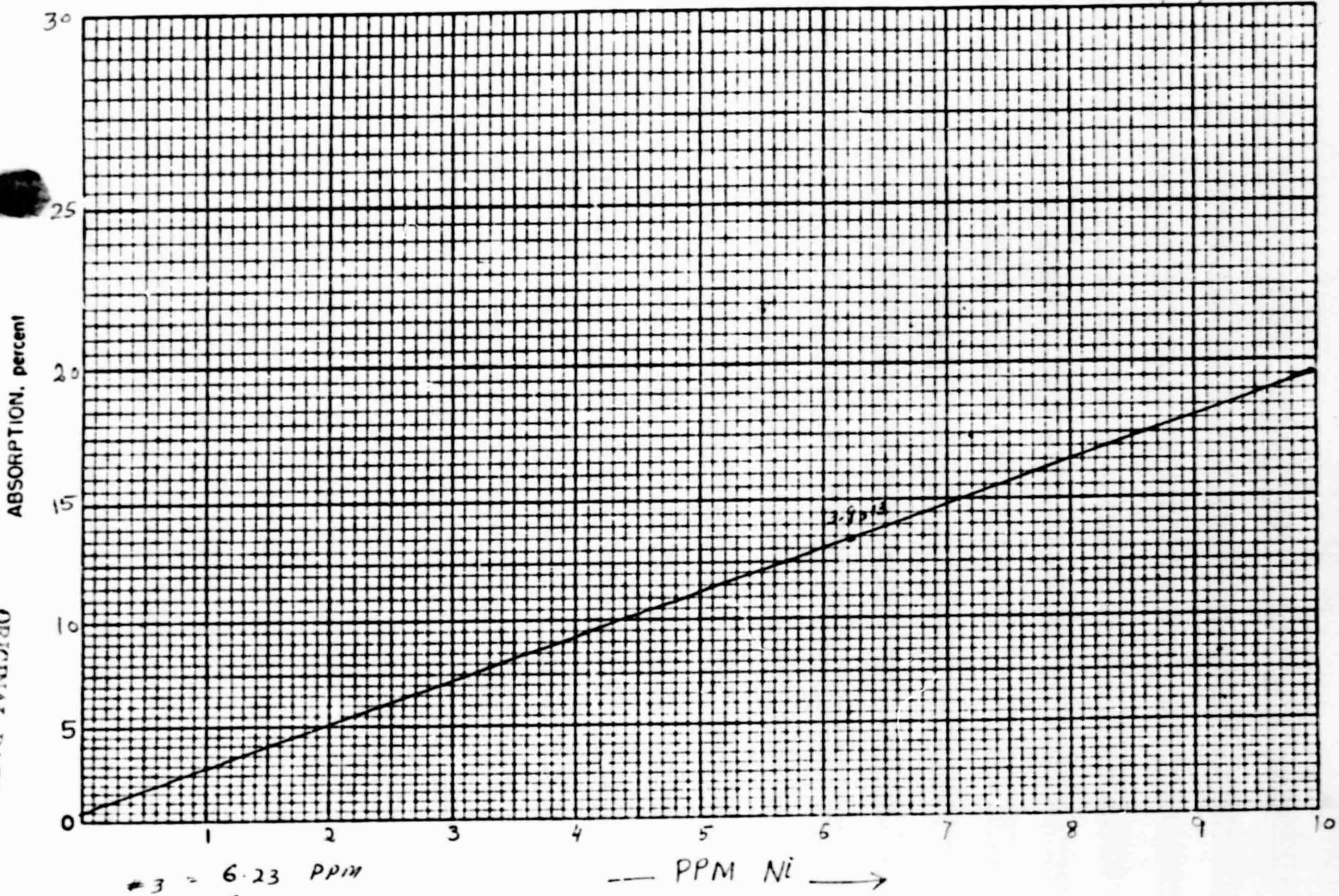
Unknown sample analysis

Table IVb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GEO AMP #3	250	.060	12.9	6.23	1557.0
GEO AMP #9	250	.060	12.9	6.23	1557.0
GEO AMP #13	250	.060	12.9	6.23	1557.0

Analysis of Samples GE 02 AM #3, #9, #13.

Graph 4



#3 = 6.23 PPM
#7 = 6.23 PPM
#13 = 6.23 PPM

Data for Graph IV

Ni analysis of cell GE 02 plates #3, #9, #13

Caliberation curve for Ni

Table IVa

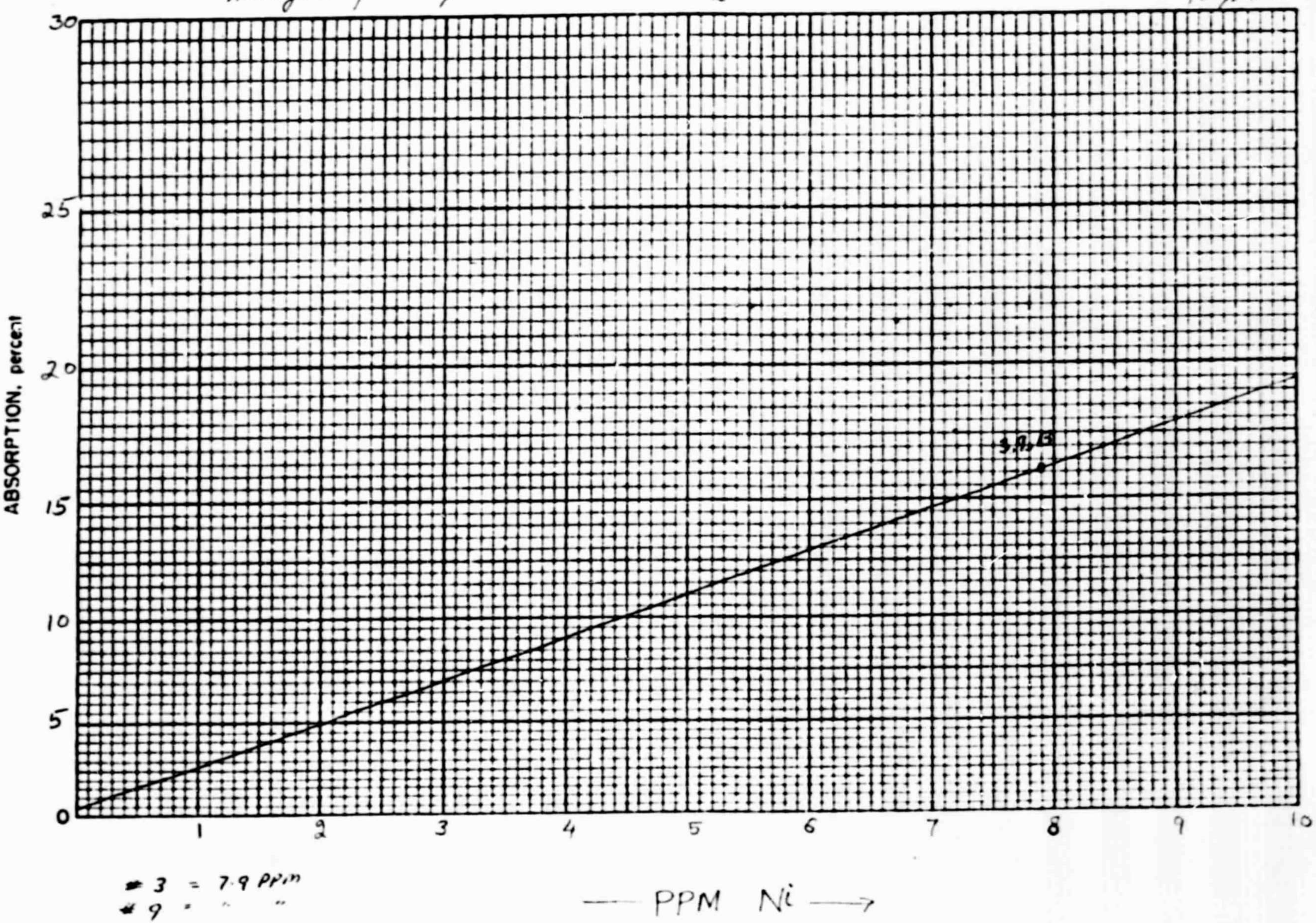
PPM	A.A. Reading	%Abs
2	.021	4.7
4	.0398	7.8
6	.0622	13.3
8	.0802	15.9
10	.0920	19.2

Unknown sample analysis

Table IVb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GEO AMP #3	250	.060	12.9	6.23	1557.0
GEO AMP #9	250	.060	12.9	6.23	1557.0
GEO AMP #13	250	.060	12.9	6.23	1557.0

Analysis of Samples 12 AM SNO_2 #3, #9, and #13. Graph 5



#3 = 7.9 ppm
#9 = " "
#13 = " "

Data for Graph V

Ni analysis of cell 12 AM SNO_2 plates #3, #9, #13

Caliberation curve for Ni

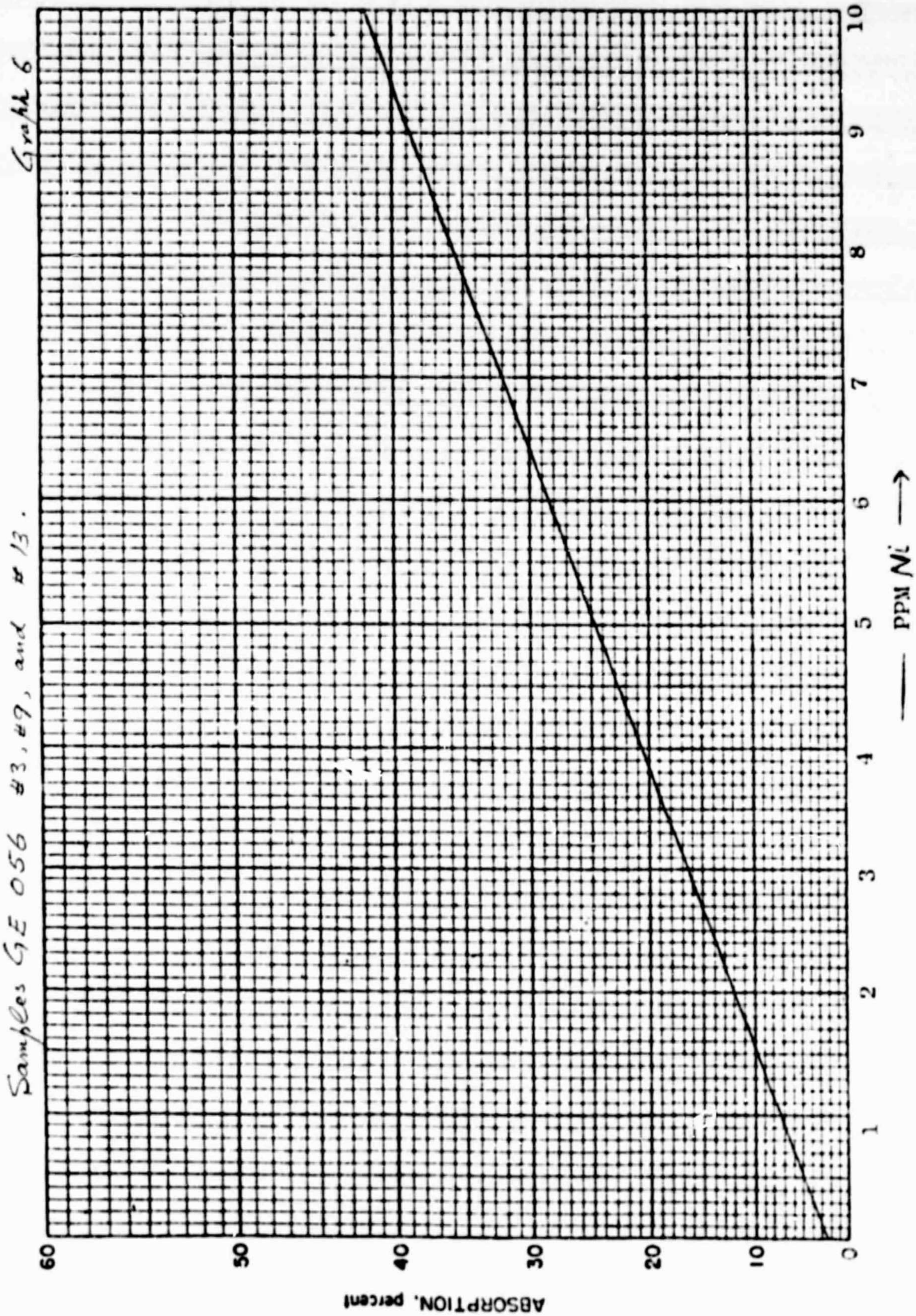
Table Va

PPM	A.A. Reading	%Abs
2	.022	5.0
4	.040	9.1
6	.060	13.0
8	.079	16.7
10	.095	19.3

Unknown sample analysis

Table Vb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
12AM SNO_2 #3	10	.077	16.3	7.9	79.0
" #9	10	.080	16.5	7.9	79.0
"	10	.078	16.4	7.9	79.0


Samples GE 056 #3, #7, and #13.
Graph 6
ABSORPTION, percent
0
10
20
30
40
50
60
PPM Ni →
1
2
3
4
5
6
7
8
9
10

Data for Graph VI

Ni analysis of cell GE 056 plates #3, #9, #13

Caliberation curve for Ni

Table VIa

PPM	A.A. Reading	%Abs
2	.053	11.5
4	.100	20.6
6	.144	28.2
8	.190	35.4
10	.220	39.7

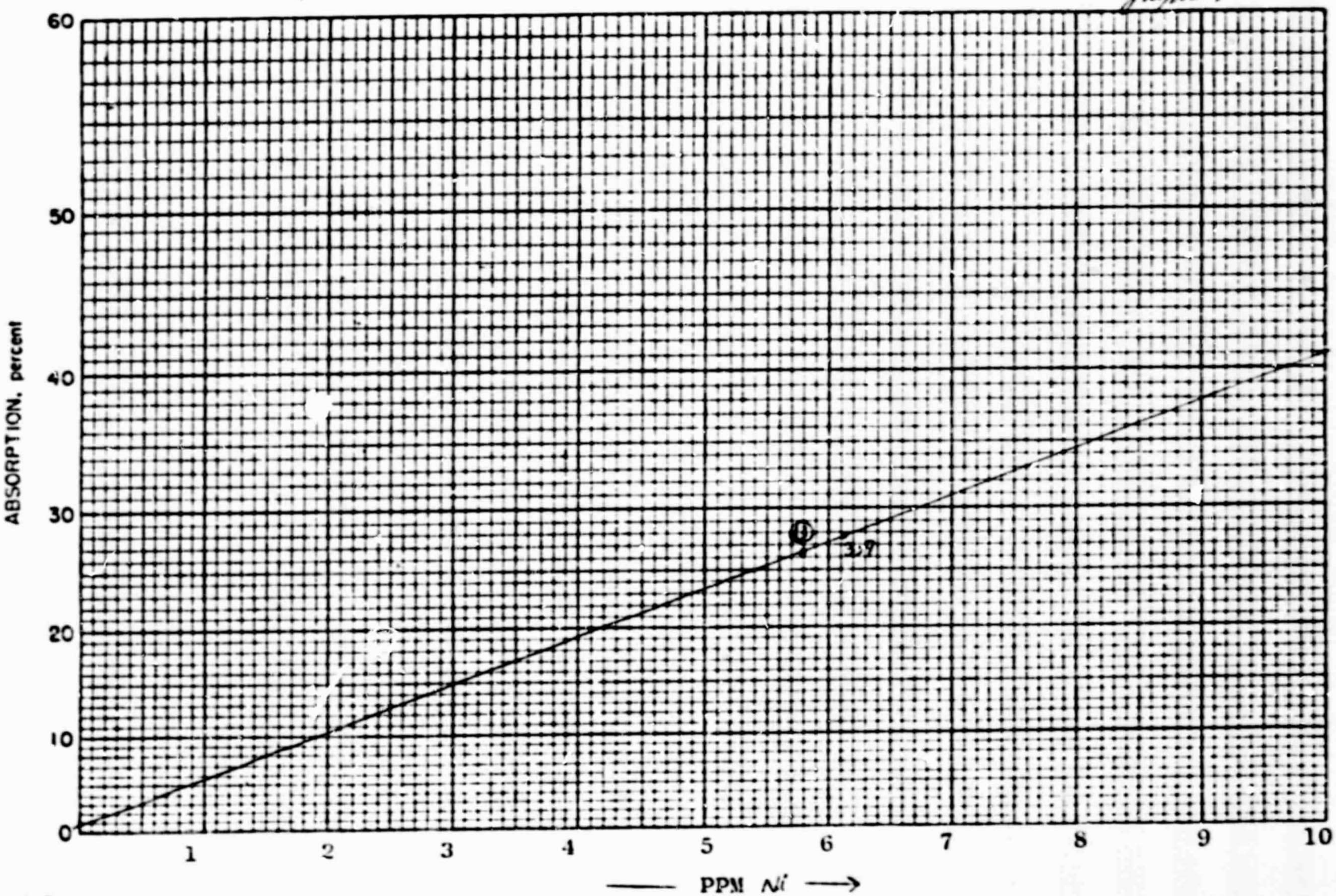
Unknown sample analysis

Table VIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 056 #3	10	.195	36.2	8.30	83.0
" #9	"	.198	36.6	8.42	84.2
" #13	"	.205	37.6	8.72	87.2

Samples GE 056 AM #3, #9, and #13.

Graph 7



#3 = 6.13
#9 = 6.13
#13 = 5.8

Data for Graph VII

Ni analysis of cell GE 056 plates #3, #9, #13, AM Extract

Caliberation curve for Ni

Table VIIa

PPM	A.A. Reading	%Abs
2	.0498	10.9
4	.0956	19.8
6	.141	27.8
8	.182	34.3
10	.215	39.1

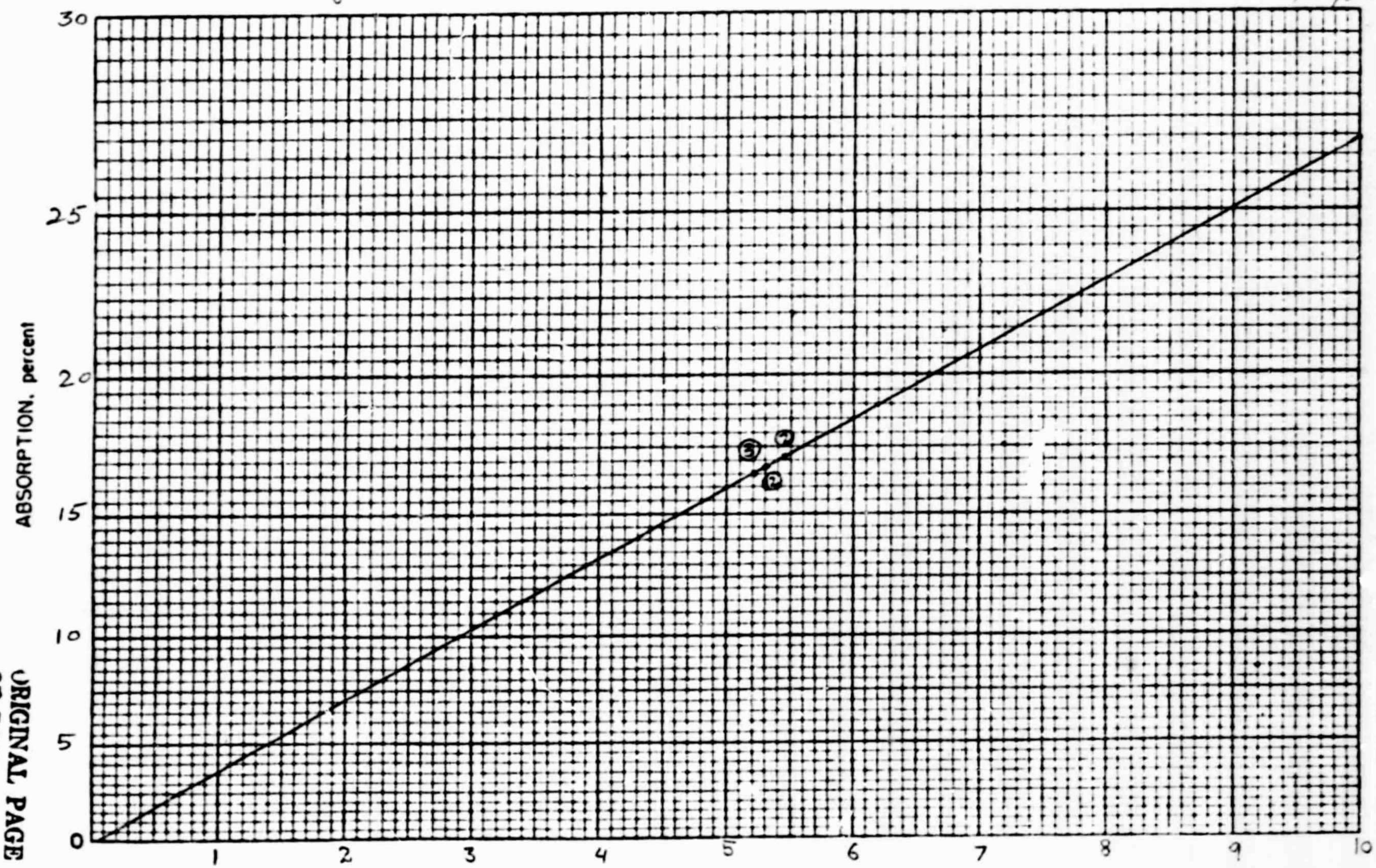
Unknown sample analysis

Table VIIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 056 #3	250	.142	27.9	6.13	1532.0
" #9	250	.141	27.8	6.13	1532.0
" #13	250	.136	26.9	5.8	1450.0

analysis of samples SN O1 positive #2, #3 and #12.

Graph 8



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#3 = 5.2 ppm
#2 = 5.43 "
#12 = 5.3 "

Data for Graph VIII

Ni analysis of cell SN 01 plates #2, #3, #12

Caliberation curve for **Ni**

TableVIIIa

PPM	A.A. Reading	%Abs
2	.031	6.8
4	.058	12.5
6	.085	17.7
8	.112	22.8
10	.136	26.9

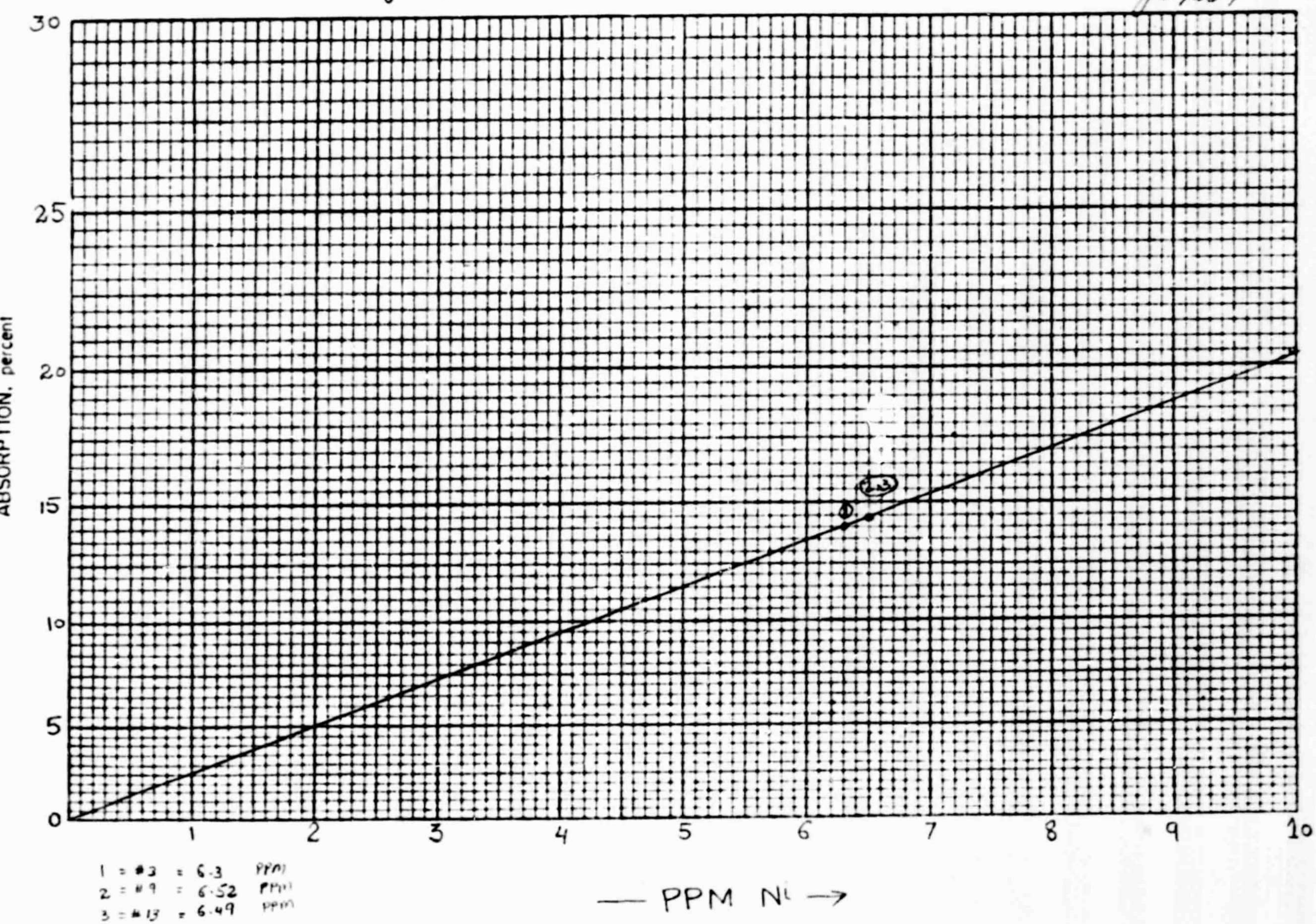
Unknown sample analysis

Table VIIIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
SN 01 #2	250	.077	16.2	5.43	1357.0
SN 01 #3	250	.073	15.5	5.2	1300.0
SN 01 #12	250	.075	15.8	5.3	1325.0

analysis of GE O2 #3, #9, and #13.

graph 9



1 = #3 = 6.3 PPM
2 = #9 = 6.52 PPM
3 = #13 = 6.49 PPM

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Data for Graph IX

Caliberation curve for Ni

Table IXa

PPM	A.A. Reading	%Abs
2	.023	5.1
4	.045	9.8
6	.064	13.7
8	.083	17.3
10	.099	20.3

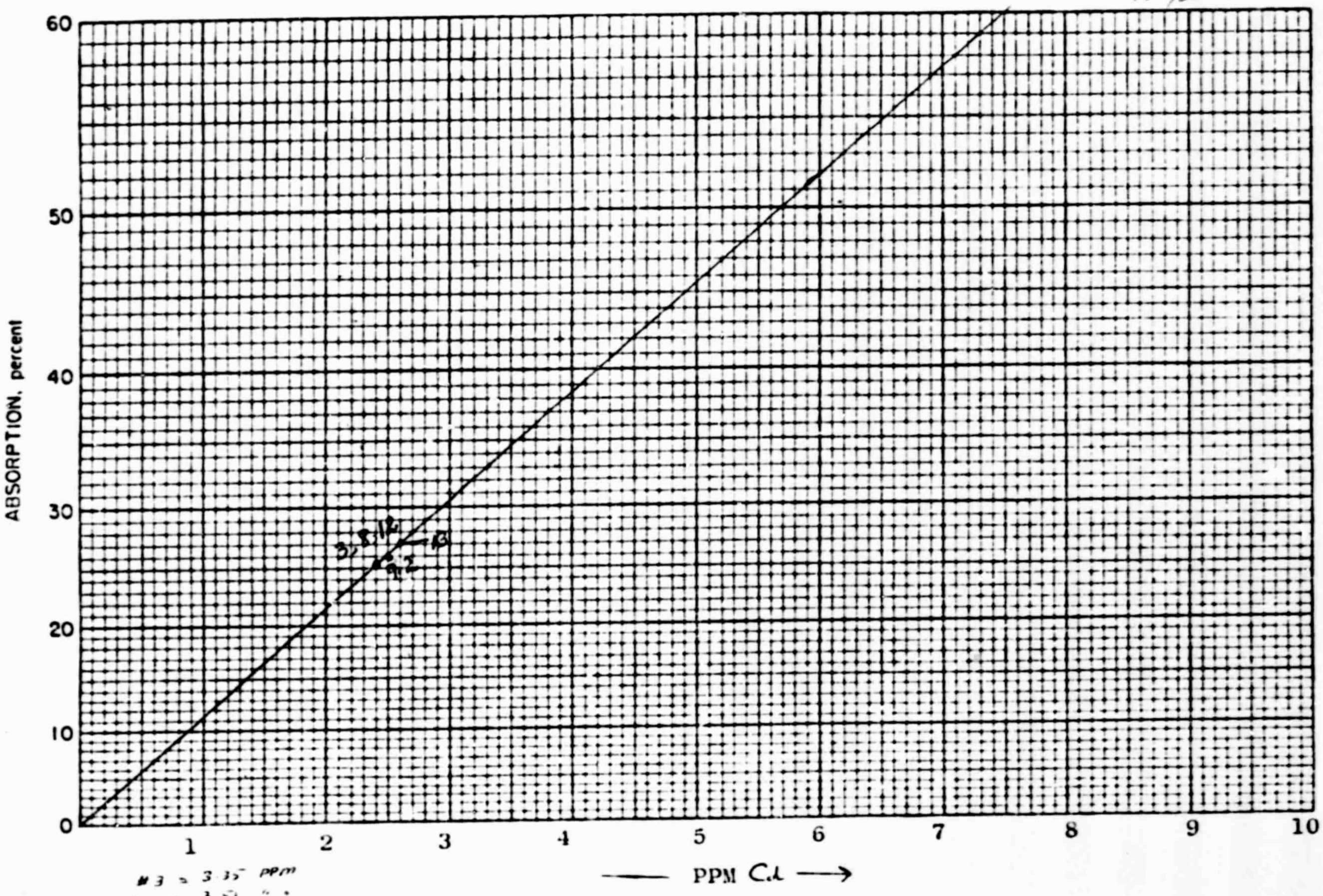
Unknown sample analysis

Table IXb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 02 S/N 01 #3	250	.066	14.0	6.3	1575.0
" #9	"	.0664	14.2	6.52	1630.0
" #13	"	.067	14.4	6.49	1622.5

Analysis of Samples GE 12 AM SN 01 Negative #3, #9 and #13
Positive #2, #8 and #12

Graph 10



#3 = 3.35 PPM
#9 = 3.51 " "
#13 = 3.60 " "
#2 = 2.49 " "
#8 = 2.41 " "

Data for Graph X

Cd analysis of cell GE 12 AM SN 01
Negative plates #3,#9, #13
Positive plates #2,#8, #12

Caliberation curve for Cd

Table Xa

PPM	A.A. Reading	%Abs
1	.065	11.5
2	.123	24.6
3	.174	33.0
4	.224	40.3
5	.267	46.0

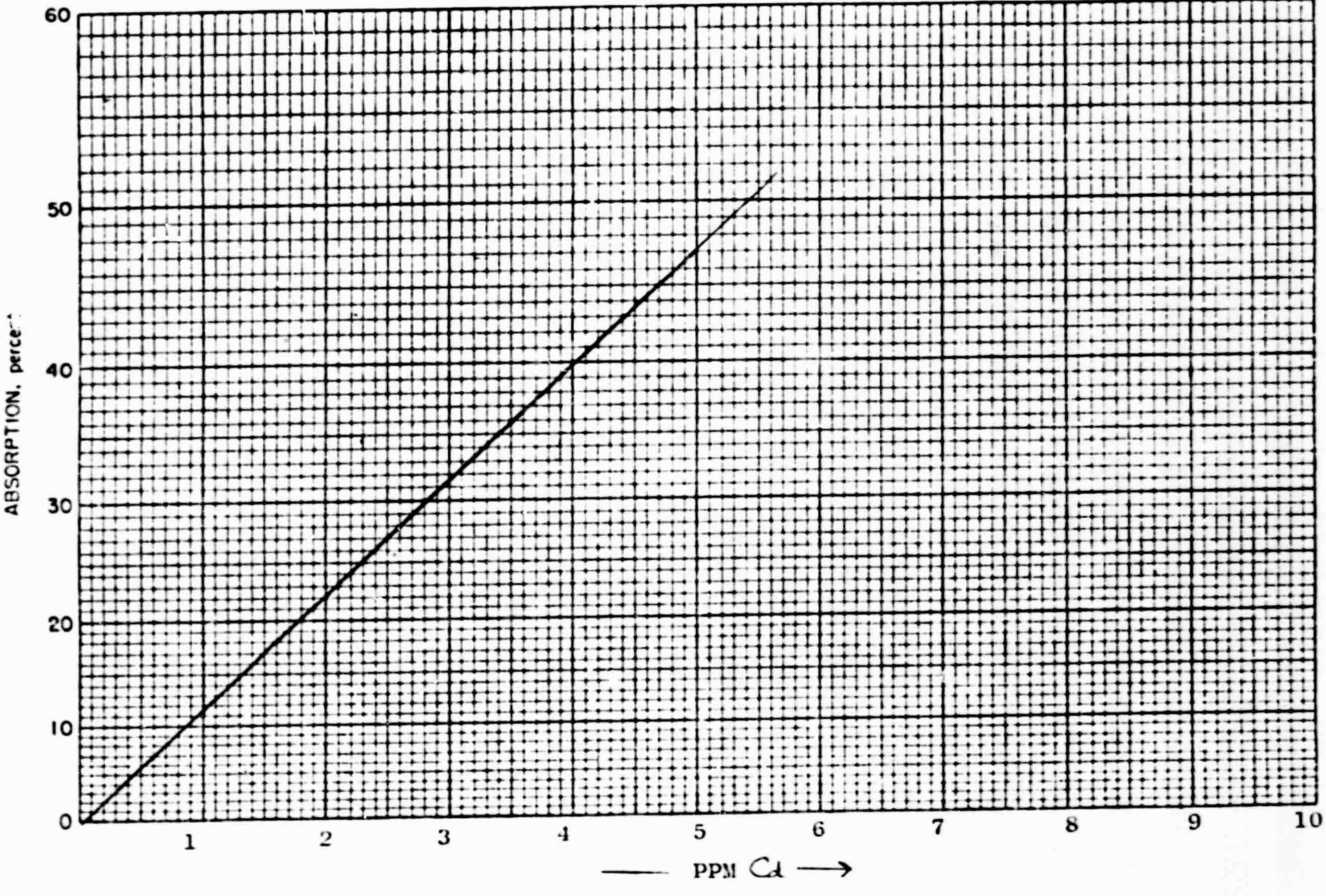
Unknown sample analysis

Table Xb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 12AM SN 01	250	.189	35.3	3.35	837
"	"	.199	36.8	3.51	877
"	"	.202	37.2	3.60	900
"	50	.146	28.6	2.49	248
"	"	.144	28.2	2.41	241
"	"	.145	28.4	2.42	242

Graph 11

A calibration curve of standard Cd solutions to verify reproducibility of curve



Data for Graph XIII

A run of known Cd solutions was madeto make sure for the reproducibility of standard **caliberation.**

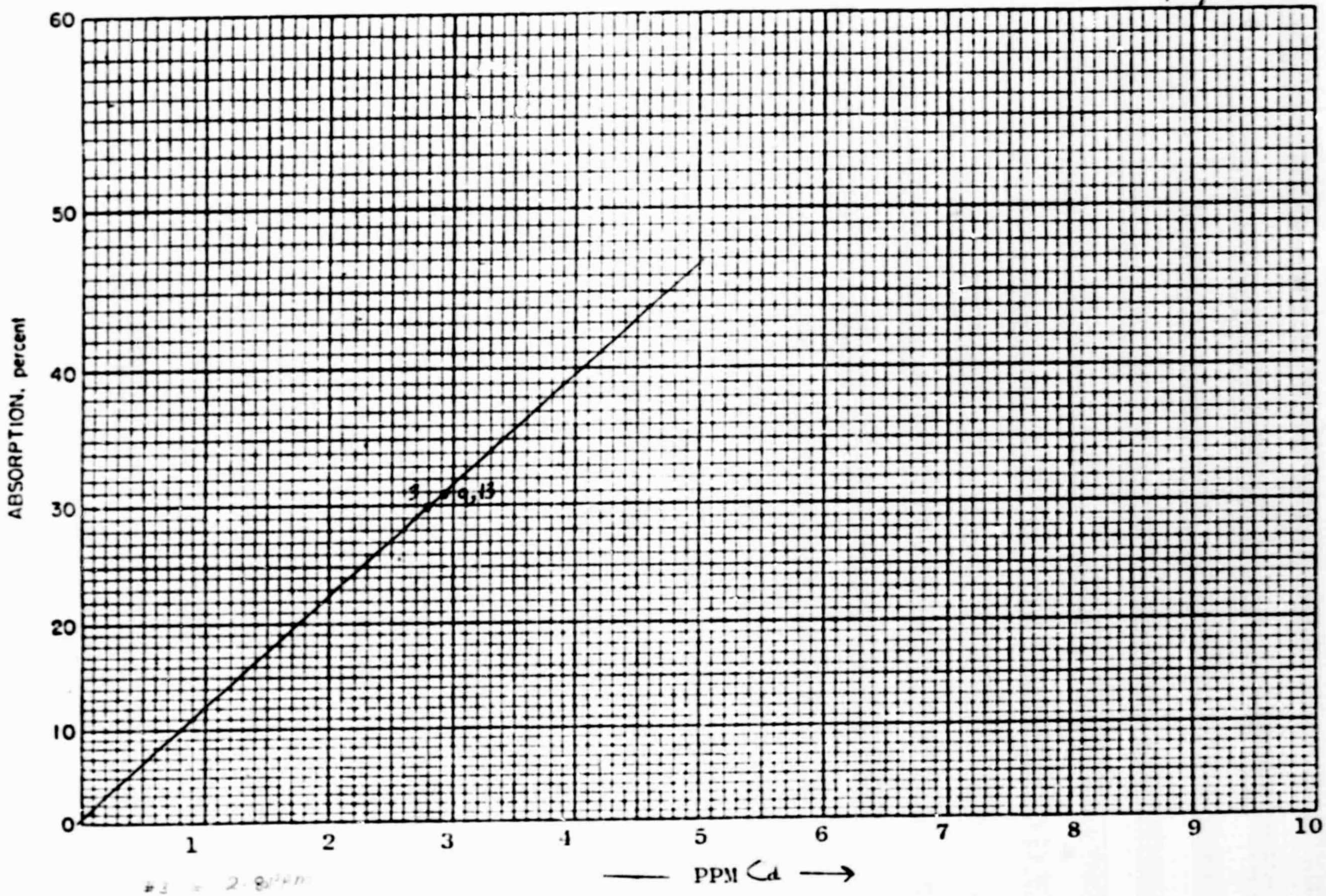
Table XIII, graph 13

PPM	A.A. Digital Readout	%Abs
1	.0658	14.1
2	.1242	24.9
3	.1766	33.4
4	.225	40.5
5	.2672	46.0

The caliberation curve is reproducible.

Samples 12 AM SNO_2 GE 02 #3, #7 and #13.

Graph 12



Data for Graph XII

Caliberation curve for Cd

Table XII d

PPM	A.A. Reading	%Abs
1	.069	14.7
2	.1276	25.5
3	.2278	33.5
4	.2714	40.8
5		46.5

Unknown sample analysis

Table XII b

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
12AM GE 02 #3	250	.1676	32.0	2.8	700
" " #9	250	.1744	33.1	2.9	725
" " #13	250	.1756	33.3	2.93	732.5

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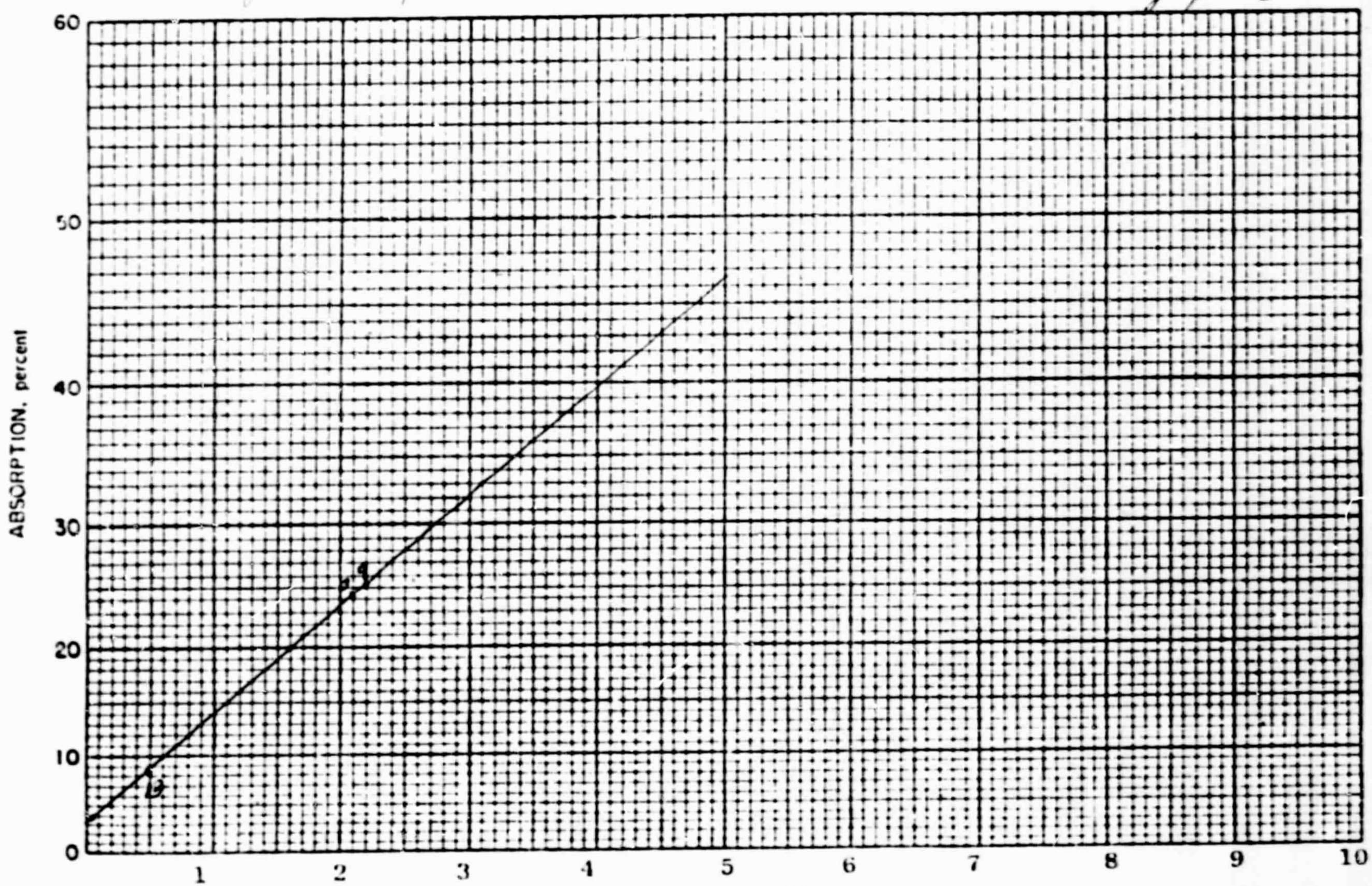
Analysis of Samples GE 02 AM+P #3, #9, and #13.

Graph 13



#3 = 2.2 PPM
#9 = 2.1 " "
#13 = 0.5 " "

Data for Graph X III

Cd analysis of cell GE 02 plates #3, #9, #13

Caliberation curve for Cd

Table X IIIa

PPM	A.A. Reading	%Abs
1	.0646	13.8
2	.1256	25.2
3	.1764	33.4
4	.2244	40.4
5	.2738	45.4

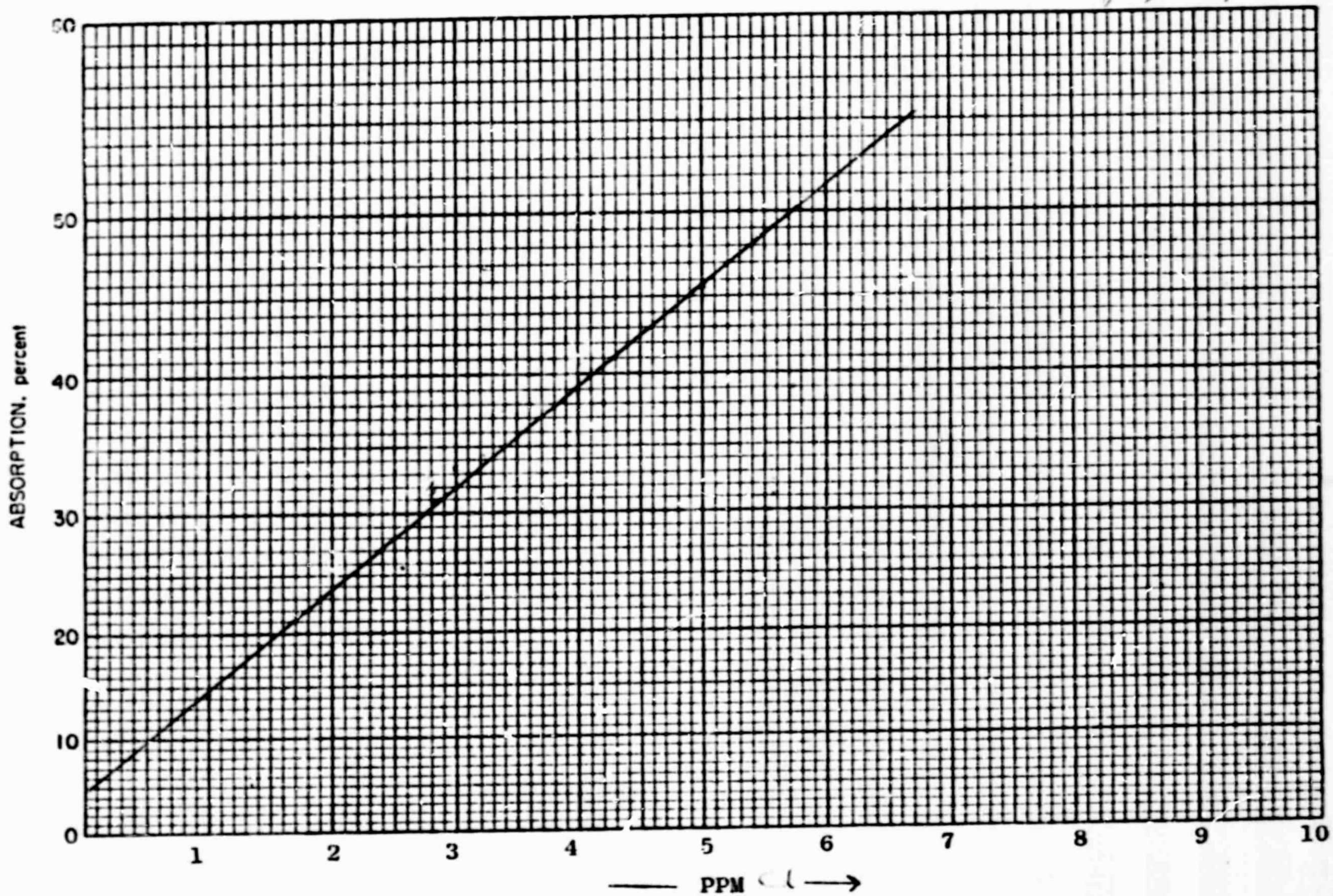
Unknown sample analysis

Table XIIIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 02 #3	0	.1356	26.8	2.20	2.20
" #9	0	.123	24.7	2.10	
" #13	0	.0322	7.1	0.5	0.50

Analysis of samples 12AH SnO_2 GE 02 #3, 9, 13.

Graph 14



#3 = 2.8 PPM

#9 = 2.9 "

Data for Graph XIV

Cd analysis of cell 12 AH SNO_2 GEO2 plates #3, #9, #13.

Caliberation curve for Cd

Table XIVa

PPM	A.A. Reading	%Abs
1	.069	14.7
2	.128	25.5
3	.177	33.5
4	.228	40.8
5	.271	46.5

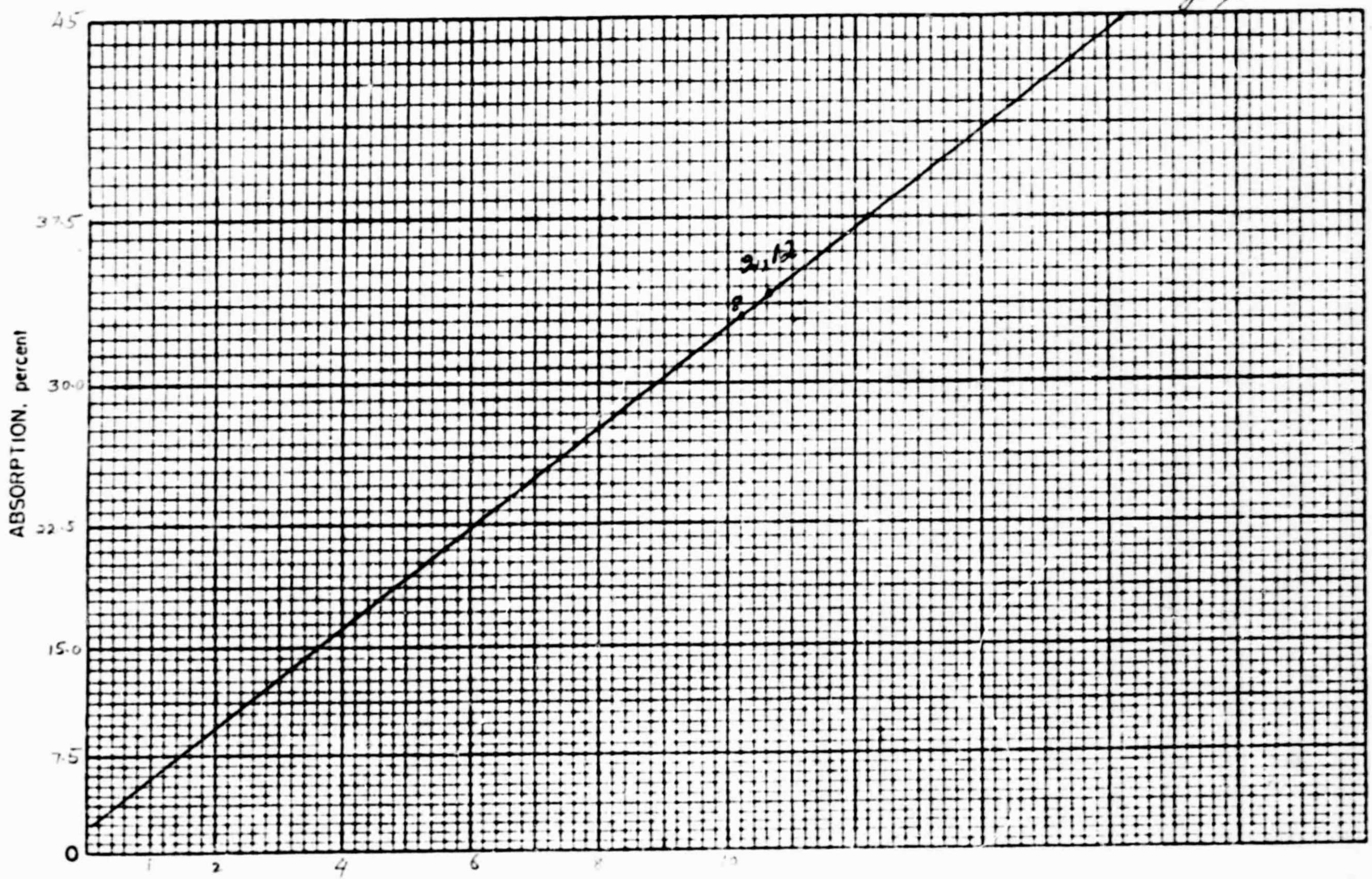
Unknown sample analysis

Table XIVb

Sample No.		Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
12 AH SNO2						
GE 02	#3	250	.168	32.0	2.80	700.0
"	#9	"	.174	33.1	2.90	725.0
"	#13	"	.176	33.3	2.93	732.5

Cold finger extract GE 056 #2, #8, and #12

Graph 15



2 = 10.35 PPM

8 = 10.20 PPM

Data for Graph XV

Cobalt analysis of cell GE 056 plates, #2, #8,

Caliberation **curve for Co**

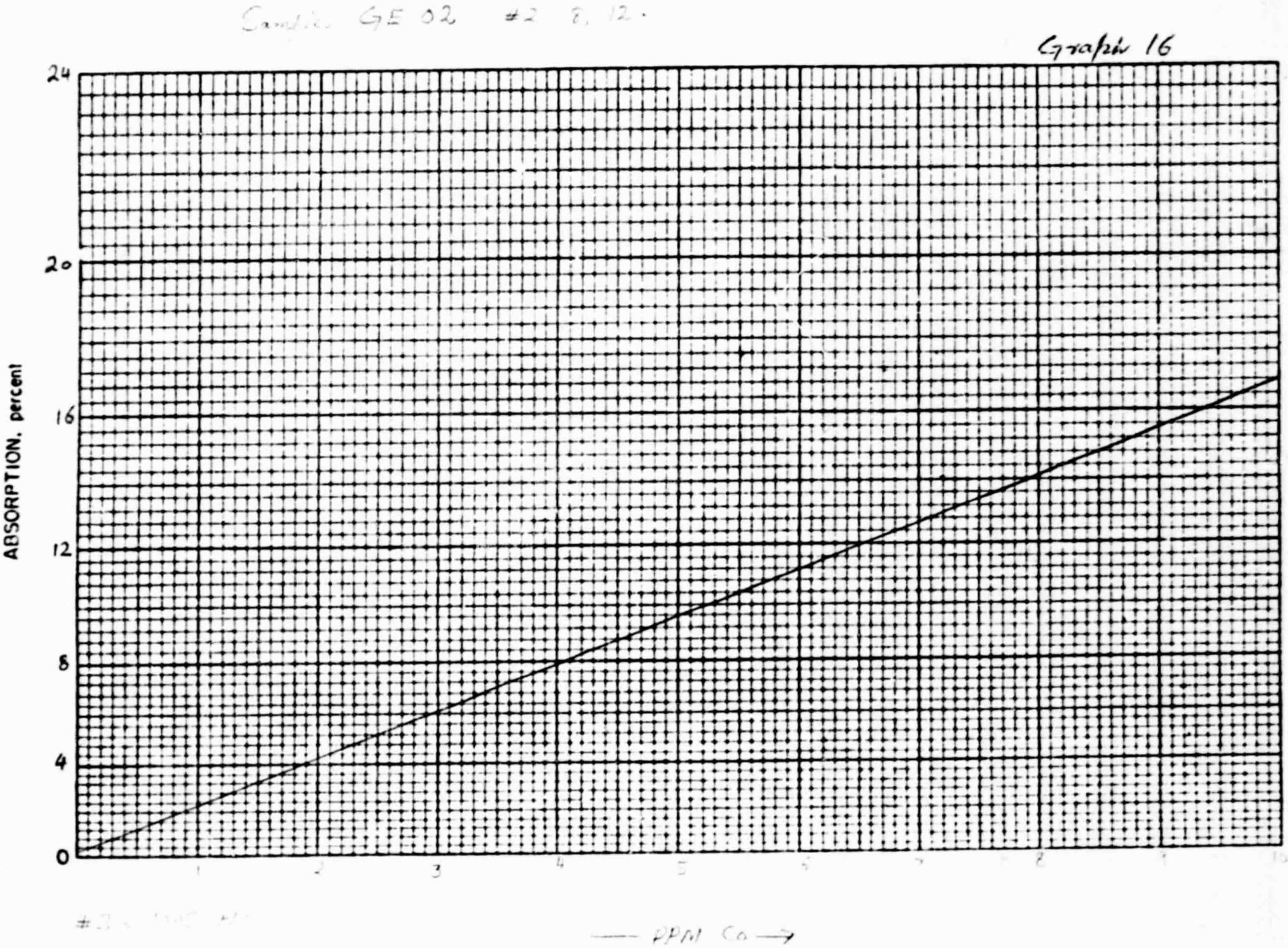
Table XVa

PPM	A.A. Reading	%Abs
1	.020	4.5
2.5	.051	11.1
4	.078	16.5
5	.096	19.9
6	.113	22.9
8	.1465	28.6
10	.173	32.9

Unknown sample analysis

Table XVb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 056 #2	5	.183	34.4	10.35	52.0
" #8	5	.179	33.8	10.2	51.0
" #12	5	.181	34.1	10.3	52.0


Sample GE 02 #2 8, 12.
Graph 16
ABSORPTION, percent
0
4
8
12
16
20
24
1
2
3
4
5
6
7
8
9
10
PPM Co

Data for Graph XVI

Co analysis of cell GE 02 Positive plates #2, #8, #12

Caliberation curve for Co

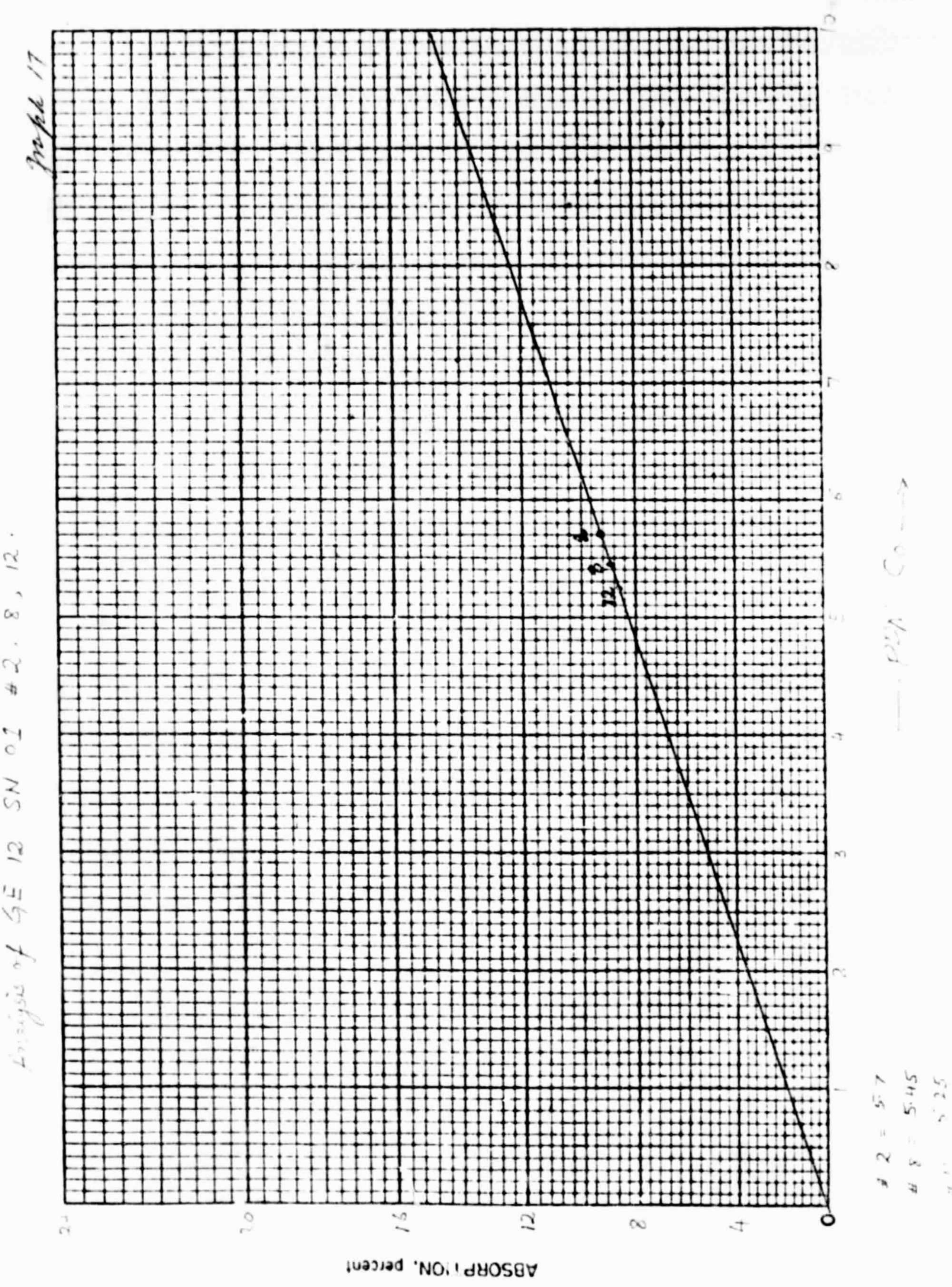
Table XVIa

PPM	A.A. Reading	%Abs
1	.010	2.3
2.5	.023	5.2
4	.036	8.0
5	.043	9.5
6	.051	11.1
8	.067	14.3
10	.081	17

Unknown sample analysis

Table XVIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 02 #2	5	.083	17.4	10.15	51.0
" #8	5	.086	17.8	10.35	52.0
" #12	5	.081	17.0	10.00	50.0


Analysis of GE 12 SN 01 #2, 8, 12
ABSORPTION, percent
0
4
8
12
16
20
24
1
2
3
4
5
6
7
8
9
10
ppm Cu
12
8
2
#2 = 5.7
#8 = 5.45
5.25

Data for Graph X

Co analysis of cell GE 12 SN/01 plates #2, #8, #12

Caliberation curve for Co

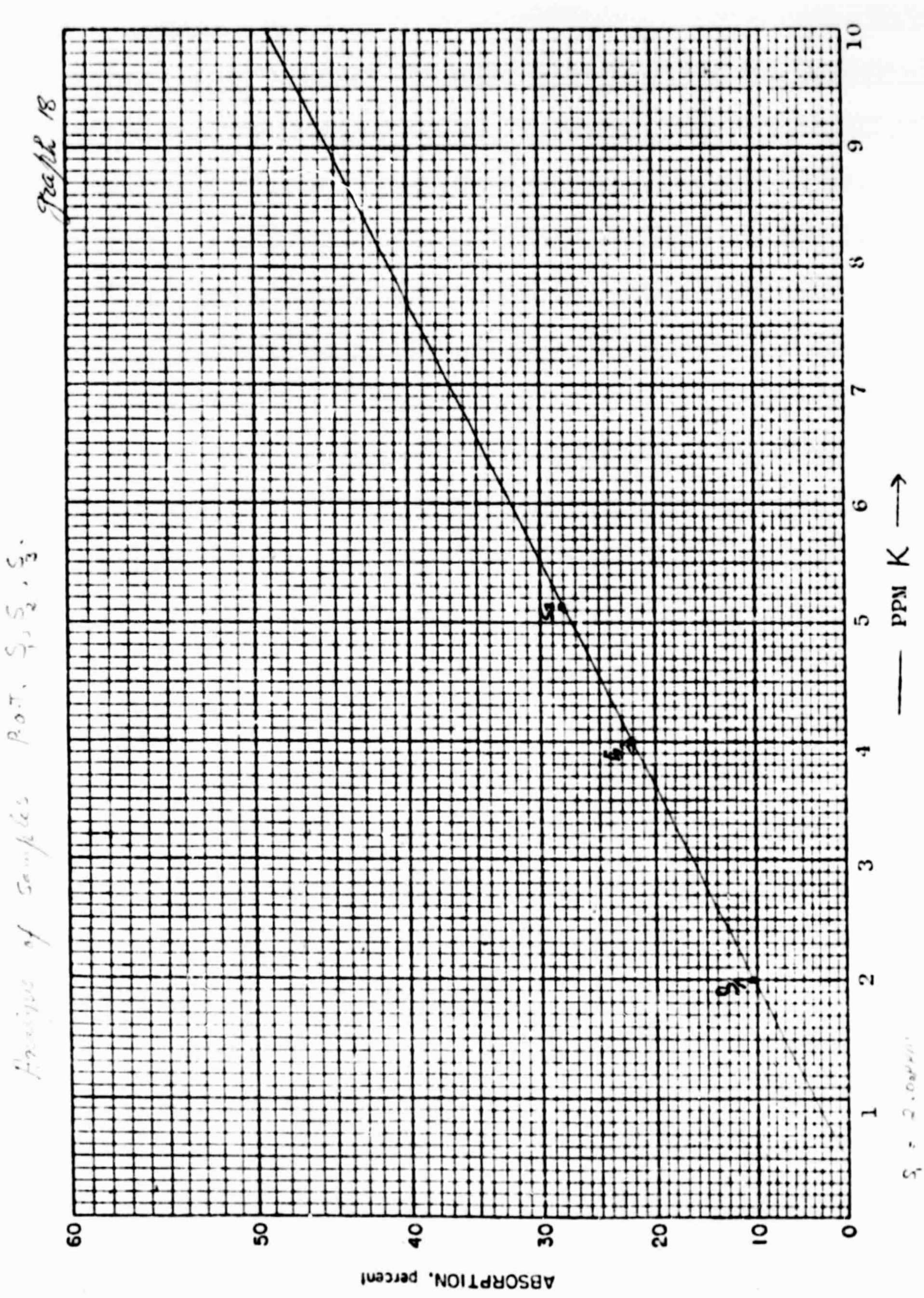
Table X VII a

PPM	A.A. Reading	%Abs
1	.007	1.6
2.5	.019	4.3
4	.030	6.7
5	.037	8.2
6	.044	9.6
8	.058	12.5
10	.070	14.9

Unknown sample analysis

Table XVII-b

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
GE 12SN 01 #2	5	.042	9.2	5.7	28.5
" 11SN 01 #8	5	.040	8.8	5.45	27.25
" " " #12	5	.039	8.6	5.25	26.25



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Data for Graph XVIII

K Analysis of plates S_1, S_2, and S_3

Caliberation curve for K

Table XVIIa

PPM	A.A. Reading	%Abs
1	.024	5.4
2	.0488	10.6
4	.1066	21.8
6	.1734	32.9
8	.2436	42.9
10	.3202	52.2

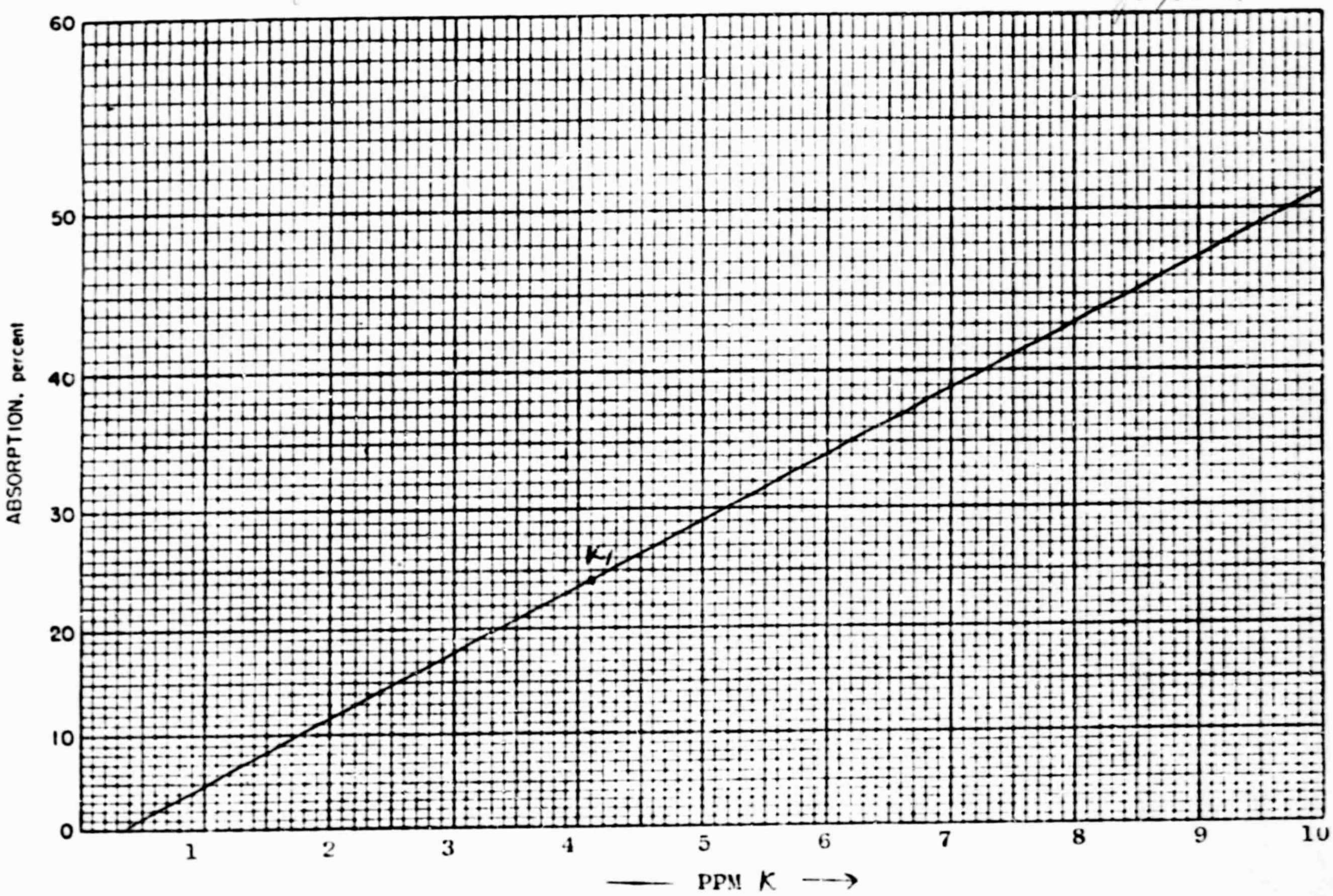
Unknown sample analysis

Table XVIIIb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
S_1	0	.0492	10.7	2.0	2.0
S_2	0	.107	21.8	4.0	2.0
S_3	2	.1458	28.5	5.15	10.30

Analysis of K_1

Graph 19



K_1 = 4.1 PPM

Data for Graph XIX

Caliberation curve for K

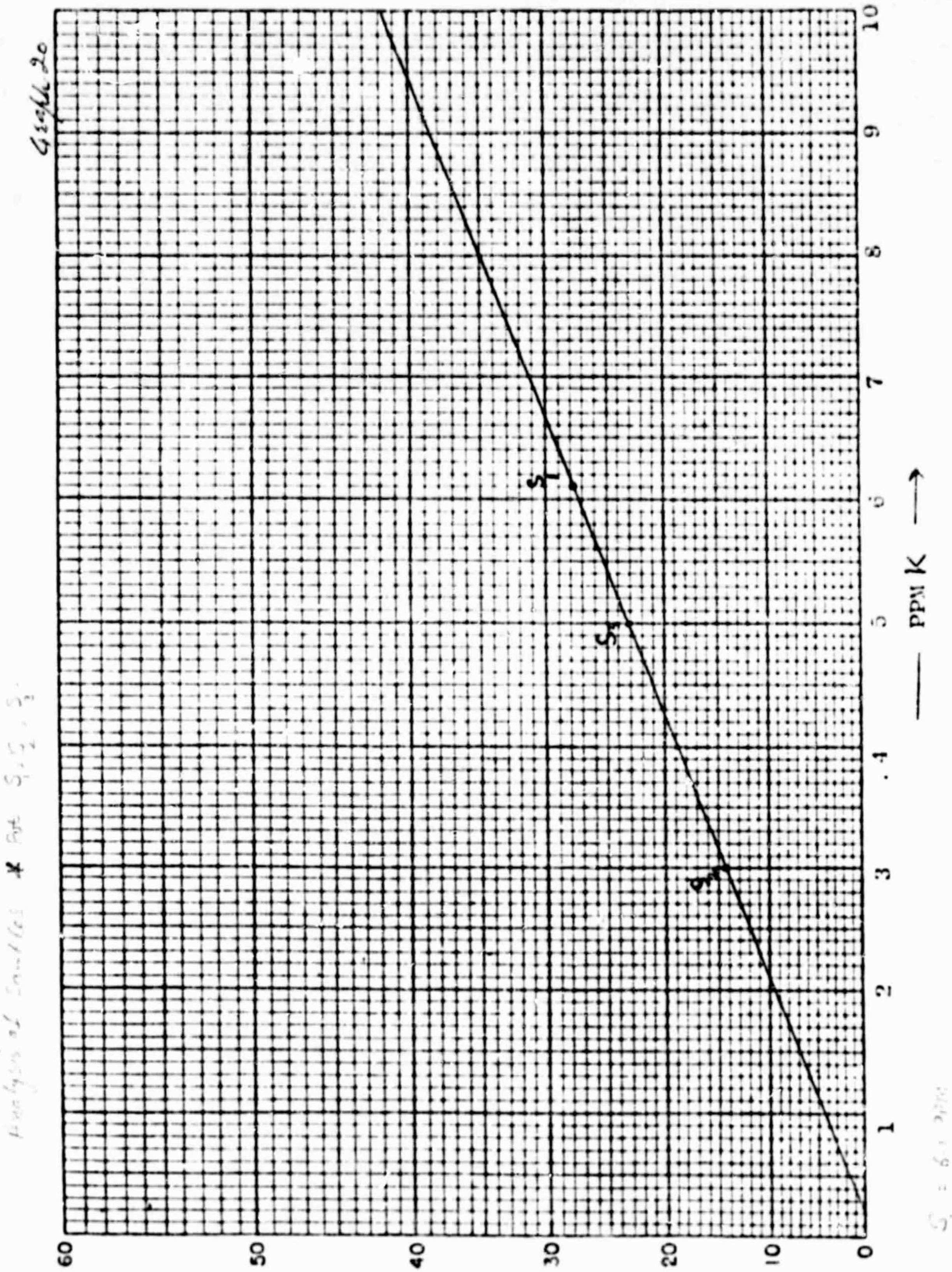
Table XIXa

PPM	A.A. Reading	%Abs
1	.028	6.30
2	.063	13.5
4	.108	22.1
6	.178	33.7
8	.257	44.6
10	.333	53.6

Unknown sample analysis

Table XIXb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
K_1	250	.114	23.1	4.1	1025.0



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Data for Graph XX

K analysis of plates S_1, S_2, S_3

Caliberation curve for K

Table XXa

PPM	A.A. Reading	%Abs
1	.0138	3.1
2	.0262	5.8
3	.0450	9.8
4	.0666	14.2
5	.0930	19.3
6	.199	24.0
7	.150	29.2
8	.176	33.3
9	.208	38.1
10	.234	41.8

Unknown sample analysis

Table XXb

Sample No.	Dilution factor	A.A reading	%Abs	PPM	PPM Orig solution
S_1	10	.121	24.3	6.1	61.0
S_2	"	.048	10.4	3.0	30.0
S_3	"	.093	19.3	5.0	50.0